bha:rati:y bha:ṣa: samsthe

acoustic characteristics of Kannada

B. B. Rajapurohit

CENTRAL INSTITUTE OF INDIAN LANGUAGES
MYSORE-570006

ACOUSTIC CHARACTERISTICS
OF
KANNADA

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OCCASIONAL MONOGRAPHS SERIES

No. 27

General Editor

D. P. PATTANAYAK

CIIL Occasional Monographs Series-27

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First Published : *June 1982, Jyeshtha 1904*

Price : Rs. 10–00

Published at the Central Institute of Indian Languages, Manasagangotri, Mysore-570006 by D.P. Pattanayak, Director and printed at M/s Meera Printers, Mysore.

FOREWORD

The Central Institute of Indian Languages was set up on the 17th July, 1969 with a view to assisting and co-ordinating the development of Indian languages. The Institute was charged with the responsibility of serving as a nucleus to bring together all the research and literary out-put from the various linguistic streams to a common head and narrowing the gap between basic research and developmental research in the fields of languages and linguistics in India.

The Institute and its five Regional Language Centres are thus engaged in research and teaching which lead to the publication of a wide-ranging variety of materials. Preparation of materials designed for teaching/learning at different levels and suited to specific needs is one of the major areas of interest of the Institute. Basic research relating to the acquisition of language and study of language in its manifold psycho-social relations constitutes another broad range of interest. The publications include materials produced by the members of the staff of the Central Institute of Indian Languages and its Regional Language Centres and associated scholars from universities and institutions, both Indian and foreign.

The phonetic studies of Indian languages have not received serious attention of Indian linguists. Acoustic studies particularly have received still lesser attention. Dr. R. N. Srivastava and Dr. B. S. Sandhu did pioneering work in the area. But their dissertations are not available in print. Apart from the occasional articles in the professional journals, acoustic studies of Indian languages are made by Djorje Kostic and his collaborators in their series of books : *A Short Outline of Bengali Phonetics, A Short Outline of Telugu Phonetics and A Short Outline of Hindi Phonetics.* The nature of those series of books is such that they give an insight into the acoustic properties of sounds of respective languages, but the functional analysis of sounds,

which a linguist aims at, was not their aim. Dr. Velayudhan had made an acoustic study of vowel duration in Malayalam. Publication of that book by the Dravidian Linguistic Association is creditable. Mrs. Nagamma Reddy has completed her acoustic studies in England. It is hoped that publication of her work will add to the literature.

In the present monograph, Dr. B. B. Rajapurohit has laid emphasis on the functional analysis. He has tried to explore the potentialities of acoustic analysis from the point of its utility for phonemic analysis. The general acoustic characteristics of Kannada sounds have also been brought out here.

Dr. Rajapurohit had been deputed to Leningrad State University, USSR, to study the techniques of acoustic analysis, under Indo-Soviet Cultural Exchange Programme. We are thankful to the Soviet authorities who provided facilities for this work. The study of acoustic characteristics of Kannada, or any language for that matter, has not ended with these results. In fact, it is a beginning. The Central Institute of Indian Languages has plans to undertake selected Indian languages for detailed acoustic study.

I hope that this book will find favour with scholars. I thank all those responsible for bringing out this volume expeditiously.

D. P. PATTANAYAK

Note on Transcription

Due to non-availability of certain conventional phonetic and other symbols in print, different symbols have been used as follows :

j	Voiced palatal affricate
ə/d̲	Voiced dental fricative
ə̣	Voiced retroflex flap
c	Voiceless dental affricate
J	Voiced dental affricate
b̲	Voiced bilabial fricative
g̲/g̲	Voiced velar fricative
m̲	Voiced labio-dental nasal
n	Voiced palatal nasal
č	Voiceless palatal affricate is shown as tš on the pictures
j	Voiced palatal affricate is shown as dž on the pictures.

Corrigenda

page	line	read	for
1	25	three districts	four districts
11	12	čikṇi	cikṇi
23	31	time	tim
28	17	allophonic	allopnonic

Acknowledgement

This report is an outcome of the research work done at the Department of Phonetics, Leningrad State University, Leningrad, USSR from October 1978 to February 1979. It was possible to complete the study in such a short period of 5 months because I had gone fully prepared to work on the topic. Though the weather was extremely cold in that year's winter the warmth I received at the Department of Phonetics, enabled me to work hard and accomplish the goal.

I must express my sincere gratitude to Dr. L. A. Verbichkaya, Reader in Phonetics, who in spite of her busy schedule spared no pains to supervise the work; to Dr. L. V. Bondarko, Head of the Department of Phonetics, for providing me with the facilities for research; to Mrs. Sherbakova for giving me the directions in deciphering the oscillograms ; to Mr. Victor Denisov, a post-graduate student, who rendered all friendly help; to all the members of the staff and the technicians, of the Department of Photetics, who in one way or the other helped the quick progress of work.

I must also thank Dr. D.P. Pattanayak, Director of Central Institute of Indian Languages, who proposed to the Government of India that I should be sent to USSR to study Acoustic Phonetics. I shall be failing in my duty if I do not thank both the Governments of India and USSR for providing me with an opportunity under the Indo-Soviet Cultural Exchange Programme. My thanks are also due to the Leningrad State University which accepted me for specialization..

Last but not the least, I must thank Shri N. H. Itagi, who prepared the map, graphs, and laid out the oscillograms and spectrograms in the press copy, Shri H. L. N. Bharati, who supervised the printing and M/s. Meera Printers, who printed the book neatly.

20th February 1980 **B.B. Rajapurohit**

CONTENTS

0. Introduction

0.1 Overview : The three branches of phonetics—auditory, articulatory and acoustic—are interdependent and complementary to each other. It has been well established that the right perception of sounds can shape the motor mechanics of articulation. Those who cannot hear are unable to speak, though he physiology of their speech mechanism might be normal. A common man, with normal hearing, develops habits of speech of the language with which he constantly comes in contact. But a trained articulatory phonetician can produce the sounds of any language because his hearing faculty would have been trained to perceive all the types of sounds and to produce any sound and to compare the result with the original. In this process the human ear performs a role which can never be replaced by any man-made machine. No microphone of a tape recorder or an oscillograph or a spectrograph can surpass it.

Acoustic phonetics studies the physical properties of sounds and provides a language to distinguish one sound from another in quality and quantity. However well-trained an articulatory phonetician be he is likely to be influenced by the speech characteristics of the language acquired by him from childhood, or before learning phonetics. In this context the mechanical study of speeh sounds can provide him with an objective view point about the speech sounds.

0.2 The Scope of Acoustic Phonetics

There have been a number of instruments and machines that have been designed for the study of physical characteristics of speech. With the laryngoscope it is possible to see the activities of different parts of the vocal cords. With palatographs, which are the impressions of articulators on an artificial palate, it is possible to study the points of articulation of some sounds and also the manner of articulation of some sounds. But the artificial palate causes some discomfort to the subject.

Hence the results are affected. Recently the Department of Phonetics of Edinburgh University has developed a technique of 'Direct palatography' by which, it is said, the impressions on the palate can be directly studied.

The classical Kymograph, which records the chest pulses quite reliably, is still indispensable to the study of the breath stream process, especially in the case of stressed vowels.

There are also separate machines to display the pitch and intensity of sounds. The 'Pitch Meter' and 'Intensity Meter' of F. J. Electronics are such machines. The 'Audio Frequency Filter' by the same company separates the frequencies for auditory discrimination of sounds. The 'Vibrator Boxes' and '48 channel audio Frequncy Filter', the potentialities of which are explored by Djorje Kostic in speech therapy, are used to discriminate between voiced and voiceless sounds by the sense of touch and to determine the degree of deafness of the ear to certain frequencies.

The Mingograph, which traces the wave form similar to the oscillograph tracings, is used for wave form analysis. It is possible to calculate the frequency of the fundamental tone (F_0), the first formant (F_1) and the bandwidth (B_1) of F_1 on the basis of the mingograph tracings[1].

By an oscilloscope the wave forms are displayed on the screen of the Cathode Ray Tube. It is possible to record them by taking a photograph with a Polaroid camera. This cumbersome process has been simplified by the Direct Recording Oscillograph, which takes the oscillograms on 35 mm film with a movie camera. The details of this machine are given in chapter 2.

The Kay Elemetrics Sonagraph is another important and useful machine. It records the time and the concentration of acoustic energy at different frequency levels by way of formants. Utterances upto duration of 2.4 seconds can be taken at a time. It also requires about 5 minute's operational time to take a spectrogram of each utterance. The spectrograms are quite wide, that is about 4 inches, to show all the variations.

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1. Gunnar Fant : "Modern Instruments and Methods for Acoustic studies of Speech" RIT Stockholm technical report No. 8, 1957. p. 32 and p. 11 of the illustrations.

The 48 channel sound Spectrograph, which takes the spectrograms on 35 mm film, can handle utterances of about 3 minutes safely with one loading of camera. It is a very convenient machine for quick extraction of Spectrograms. Since the area in which the Spectrograms are marked is only 24 mm wide it is difficult to read them accurately with bare eyes. A 'Reader' is used for the purpose. But from the point of speed of operation there is nothing like this machine. The details of this machine are given in chapter 3. Gunnar Fant has also described a similar kind of machine designed by H. Sund at the Royal Institute of Technology, Stockholm [1]

There are a number of other machines such as Spectrometer, Glottograph, etc, which are used for obtaining different kinds of readings for different purposes. The physicists and the communication engineers, who are also engaged in studying the physical properties of sounds, make use of different kinds of machines depending upon their purpose. X-ray studies of the activities of the vocal tract are also made[2].

0.3. The Extent of Acoustic study

The acoustic study in itself is of secondary importance to linguists, because, linguists are primarily interested in the functional analysis of speech sounds. The answer to the question whether acoustic phonetics can be of any help in the functional analysis of speech sounds is in the negative.[3] Ultimately, the linguists aim at the phonemic system of the language. Acoustic phonetics cannot do the phonemic analysis. However, the techniques of acoustic phonetics can be of great help in the phonetic analysis of the functionally established units and in the study of the general relations between various stages of a speech event.[4]

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1. Gunnar Fant, op. cit. Page 29.
2. Gunnar Fant : 'Acoustic Theory of Speech Production' Mouton, the Hague 1964.
3. Eli Fischer—Jørgensen: "What can the new techniques of acoustic phonetics contribute to Linguistics". Proc. VIII Int. Cong. of Linguists, 1957, p 477.
4. Op. cit. p. 478.

The present study, 'Acoustic Characteristics of Kannada' begins with the phonemic analysis of the language. The duration, intensity and frequency of vowels and consonants are studied on the basis of oscillograms. The formant frequencies and their structure are also studied on the basis of spectrograms. It may be noted that both the oscillographic and the spectrographic studies have something to contribute to the phonemic analysis, as it is evident from the observations made at the end of each analysis. But both studies act as confirmatory tests for the large part of phonemics. Yet, some of the judgments made by auditory phoneticians could not be tested by either analysis. It may be concluded that though auditory phonetics takes precedence over acoustic phonetics in the phonemic analysis, the latter checks and quantifies the nature of sounds for better understanding of the relationships of sounds.

0.4. The limitations of the present study

The present acoustic study is made on the basis of the author's own speech recordings. Hence, the individual idiosyncrasies in pronunciation are likely to be ascribed to the language. It would be ideal to get the same data pronounced by 3–4 other speakers also, so that the acoustic characteristics of Kannada would get objectively established.

Ideally, the data should have been designed specially for acoustic experiments. Since the study was begun with the phonemic analysis, the same data was used for acoustic analysis also. Thus it was observed that a part of the data that was needed for acoustic analysis was not available ; and that a part of the data which was necessary for phonemic analysis was a repetition for acoustic analysis. In other words, it would have been possible to arrive at the same results with a smaller amount of data, organised with a view towards the experiments, and some more data specifically required for acoustic experiments could have been added. However in such a short time of five months, the results that are brought out are far more than gratifying.

CHAPTER 1

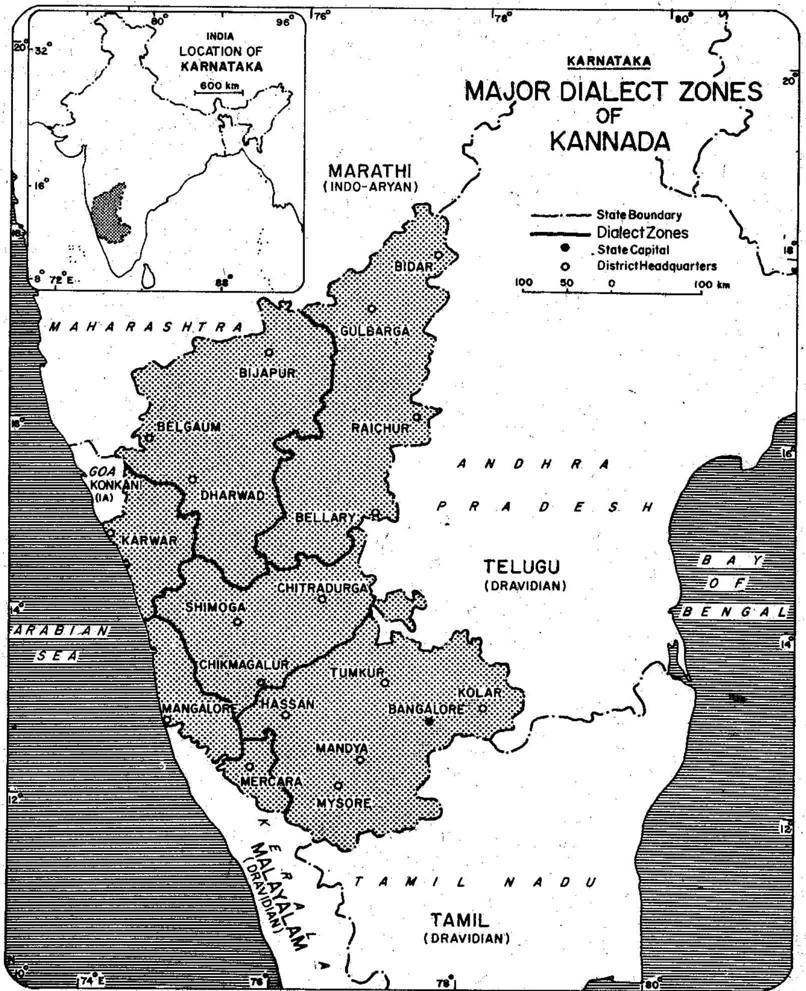
Phonemics

1. 1. Background about the linguistic area of Kannada

The Kannada language, one of the four major Dravidian languagesof South India, is the state language of Karnataka, and is spoken by about 20 million people. It has a long linguistic history of about 1,500 years and had a continuous literature for over 1,200 years. Three main stages in the history of Kannada language and literature have been identified. They are: (1) old Kannada (2) medieval Kannada (3) modern Kannada. Old Kannada is not completely intelligible to the speakers of modern Kannada. The language has undergone a number of changes in phonology and morphology through the stages of its history. Some phonemes, for instance, are lost and some others have been added and still others have undergone a change of quality. Some of the phonemes are borrowed into modern Kannada from other languages with which it came in contact. The Kannada language is spoken all over the State, which is spread over an area of about 400miles north-south and about 250 miles east to west. Geographically, the western part along the sea coast, is separated from the rest of the area by high mountain ranges. Politically, till 1956, the three districts of the northern part were within another State where an Indo-Aryan language, Marathi is spoken. In the southern districts, there was a monarchy at Mysore. The four districts of the north eastern part were in the Nizam'sDominions, where Urdu was spoken. In the south western part, Koḍagu, an independent Dravidian language, is spoken in Coorg district. Similarly in South Kanara district, Tuḷu, another independent language, belonging to the Central Dravidian group, is spoken. In both these districts, Kannada is learnt as a second language. Now, the Kannada language is the language of their education and literary expression.

These geographical and political factors have been responsible for bringing up at least seven clearly identifiable dialects or the regional varieties of Kannada. Some people identify as many dialects as there are districts i. e. nineteen. In each region, again there are 2-3 social dialects. The following map will give an idea about the regions and the regional dialects. The data for the acoustic analysis are drawn from the author's own speech.

The present author comes from Dharwar district in the northern part. He was born, brought up and educated in that district. He lived in South Kanara district for four years when he was a lecturer in Kannada in a college. For the past eight years he is living in Mysore where he is working as a Reader cum-Research Officer in Central Institute of Indian Languages. He is a speaker of the Brahmin social dialect. Hence the phonology outlined here holds good for the dialect represented by his speech. Because of his contact with the Kannada dialects spoken in South Kanara and Mysore districts, the possibility of appearance of some words and phrases from those dialects cannot be ruled out.



Based on a map approved by Survey of India

N.H. ITAGI

1. 2. Inventory of Kannada Phonemes[6]

Consonants : There are 33 consonant phonemes in the dialect under description. It may be noted that all the illustrations in this section are in phonemic script.

		Bilabial		Labio Dental	Dental		Retroflex		Palatal		Velar		Glottal
		vl	vd	vd	vl	vd	vl	vd	vl	vd	vl	vd	vl
Plosives	Un	p	b		t	d	ṭ	ḍ			k	g	
	As	ph	bh		th	dh	ṭh	ḍh			kh	gh	
Affricates	Un								č	j			
	As								čh	jh			
Nasals			m			n		ṇ				ṅ	
Fricatives					s		ṣ		š				h
Liquids	Laterals					l		ḷ					
	Trill					r							
Seme vowels				v						y			

vl = voiceless, vd = voiced, Un = Unaspirated, As = Aspirated

[6] The foregoing phonemic analysis is from my book : Intensive Course in Kannada. Pub : D. V. K. Murthy, Mysore-4 1975 pp. 90-100.

Allophones: All the phonemes, tabulated above, have the phonetic realisations indicated. Some of the phonemes have additional allophones under definable conditions. Those are listed below :

/d/ realises [ə], a voiced dental fricative, between vowels.

/ḍ/ realises as [ə̣], a voiced retroflex flap, between vowels.

/č/ and /j/ realise respectively as [c] and [J] dental affricates respectively voiceless and voiced when followed by a high back vowel.

/k/ realises as [k>], a back velar voiceless plosive when followed by a high back vowel.

/g/ realises as [g̱], a voiced velar fricative between vowels.

m/ realises as [m̱], a voiced labio dental nasal before /y, r, l, v, š, s, h/

/n/ realises as [n͠], a voiced palatal nasal, before palatal affricates, when there is no ≠ in between.

/v/ realises as [w], a voiced bilabial semivowel, when followed by a high back vowel.

/h/ realises as [φ], a voiceless bilabial fricative when followed by a voiceless bilabial stop and as [x], a voiceless velar fricative when followed by a voiceless velar stop.

• NOTE : (ṅ) has been treated as a phoneme because it distributionally contrasts with other nasals in cluster pattern.

Distribution of consonant phonemes : The following chart shows the distribution in the initial and the medial positions. The numbers indicate the occurrence and refer tothe corresponding examples in the 'Key to the Chart' No consonant occurs word finally. A blank indicates the impossibility of occurrence or the non-availability at the moment.

Phoneme	Initial	Medial	Phoneme	Initial	Medial
p	1	2	čh	35	36
ph	3	4	j	37	38
b	5	6	jh	39	40
bh	7	8	m	41	42
t	9	10	n	43	44
th	11	12	ṇ		45
d	13	14	ṅ		
dh	15	16	s	46	47
ṭ	17	18	ṣ		48
ṭh	19	20	š	49	50
ḍ	21	22	h	51	52
ḍh	23	24	l	53	54
k	25	26	ḷ		55
kh	27	28	r	56	57
g	29	30	v	58	59
gh	31	32	y	60	61
č	33	34			

Key to the Chart :

1. pəri 'manner'
2. apara 'other worldly'
3. phala 'fruit'
4. kapha 'phlegm'
5. bəri 'empty, mere'
6. sabara 'sack on the back of ox'
7. bhara 'speed, tempo'

8.	abhaya	'fearless'
9.	taḷa	'bottom'
10.	a:ta	'he'
11.	thəḷi	'sprinkle of water.
12.	athava:	'or'
13.	daḷa	'petal, army'
14.	a:da	'relative participle of verb a:gu to become'
15.	dhana	'wealth'
16.	vidhava:	'widow'
17.	ṭagaru	'ram'
18.	o:ṭa	'run'
19.	ṭhi:vi	'stature, pose'
20.	maṭha	'holy place, Mutt'
21.	ḍabbi	'tin'
22.	o:ḍu	'to run'
23.	ḍha:ḷa	'bright'
24.	diḍhi:r	'sudden, instant'
25.	kəvi	'poet'
26.	a:kaḷa	'cow'
27.	khare:	'true'
28.	le:khi:	'in writing'
29.	gəvi	'cave'
30.	a:gaḷe	'then' (past time)
31.	ghəṭṭi	'solid'
32.	saṅgha	'association, Union'
33.	ča:ḷi	'habit'
34.	i:čala	'date, a palm tree'
35.	čhəḷi	'cold'
36.	hačha:	'sound made to ward off a dog'
37.	ja:ḷigi	'net, thread for the top'
38.	gi:jaga	'a kind of bird'
39.	jhagaḷa	'quarrel'
40.	jhanjha:va:ta	'tempest'
41.	məni	'house'
42.	bhi:ma	'a personal name'
43.	nədi	'river'
44.	he:nu	'louse'

45.	heṇa	'corpse'
46.	sa:la	'debt'
47.	khi:su	'a kind of dish'
48.	viṣa	'poison'
49.	šagaṇi	'cow dung'
50.	məši	'ink'
51.	həṣi	'wet, moist'
52.	məha:	'big'
53.	la·li	'lullaby'
54.	li:la:	'play'
55.	ga:ḷi	'wind'
56.	ra:ši	'heap'
57.	va:ra	'week'
58.	vara	'bridegroom'
59.	həva:	'wind'
60.	ya:ru	'who'
61.	sa:yi	'(you) die!'

Supplementary data for unillustrated allophones:

62.	čuṭṭa	'beedi, cigar'
63.	hi:ču	'bud'
64.	ju:ju	'gamble'
65.	ka:ju	'glass'
66.	kuri	'sheep'
67.	ba:ku	'bench'
68.	u:ru	'village'
69.	ba:vu	'gout'

The following chart shows the distribution of consonant phonemes in gemination and cluster pattrens. At the junction of horizontal and vertical columns, the geminations and clusters occur. The numbers in the chart refer to the corresponding examples in the key. The geminations and clusters may occur in other examples also. But the chart focuses its attention on all possible occurrences. A blank in the chart indicates an impossibility of occurrence or its non-availability at the moment. Some of the geminations and clusters occur with a word juncture in between. Such cases are indicated by brackets. Some may occur in both the patterns—i.e., with juncture and without juncture. In such cases words without juncture have

C_1 \ C_2	p	ph	b	bh	t	th	d	dh	ṭ	ṭh	ḍ	ḍh	k	kh	g	gh	č	čh	j	jh	m	n	ṇ	ṅ	s	ṣ	š	h	l	ḷ	r	v	y
p	70	(71)	(72)	(73)	74	(75)	(76)	(77)			(78)		79	(80)	(81)	(82)	(83)	(84)	(85)		(86)	(87)			(88)		(89)	(90)	(91)		92		93
ph																																	
b	(94)		95	(96)	(97)		98	99					100	(101)	(102)				(103)		(104)	(105)			(106)			(107)			108		109
bh																																	
t	110	111	(112)		113	114	(115)						116		117				(118)		119	120			121		(122)	(123)	124		125	126	127
th																																	
d			128	129	(130)	(131)	132	133			(134)		(135)		136	137			(138)		139	(140)			(141)		(142)	(143)	144		145	146	147
dh																																	
ṭ			(148)	(149)	150	(151)	(152)	(153)	154	155			(156)		(157)				(158)		(159)		(160)		(161)		(162)	(163)		164	165		166
ṭh																																	
ḍ			(167)		168		(169)	170			171		172		(173)				(174)		175		(176)		177			(178)		179	180		181
ḍh																																	
k	182		183		184		185	(186)					187	188	(189)		(190)		(191)		192	193	194		195	196	197	(198)	199	200	201	202	203
kh																																	
g			(204)		205			(206)					(207)		208																		
gh																																	
č			(209)		210		211				212		213				214	215										(216)					217
čh																																	
j																			218									(219)			220	221	222
jh																																	
m	223		224	225	226		(227)	(228)	229	230	231		(232)	233	(234)		235	(236)	(237)		238	(239)	240		(241)		(242)	(243)	244		245		246
n			(247)	(248)	249	250	251	252					253	(254)	(255)		(256)		(257)		258	259			(260)		(261)	(262)	(263)		(264)	265	266
ṇ			(267)	(268)	(269)		(270)		271	272	273		274		(275)						(276)		277		(278)		(279)	(280)					281
ṅ													282	283	284	285					286	287											
s	288				289	290							291								292	293			294				295		296	297	298
ṣ	299								300				301																				302
š					303												304				305						306		307		308	309	310
h																									311						312		313
l	314		(315)		316		317						(318)		(319)		(320)				321				322			(323)	324			325	326
ḷ																																	
r	327			328	329		330	331					332		333	334	335		336		337		338			339		340	341		342	343	344
v																									345			346	347	348	349	350	351
y			352		353		354						(355)	356	357							(358)											359

been illustrated. It is presumed that these cases will help the study of the effect of juncture on adjacent consonants. The boundary of a word is taken in this way : inflected and derived words and exocentric constructions are taken as single words, hence with no word juncture. Other combinations of words are taken to be with word juncture.

Key to the chart :

70	appa	'father'
(71)	sapphala	'tasteless fruit'
(72)	apbᵊrli	'let father come'
(73)	upbha:rᵊdᵊ	'salt is heavy'
74	gupta	'secret'
(75)	dhapthᵊḍi	'thick saddle'
(76)	tᵊpda:ri	'wrong path'
(77)	dhapdha:ra	'thick thread'
(78)	tᵊpḍabbi	'wrong tin'
79	upka:ra	'obligation'
(80)	upkha:ra	'salt (and) pungent'
(81)	dapgᵊri	'thick branch'
(82)	kᵊpgha:li	'black wheel'
(83)	kᵊpčamča	'black spoon'
(84)	tupčhᵊltyu	'ghee was spilt'
(85)	kᵊpjana	'black people'
(86)	sapma:ri	'pale face'
(87)	upni:ru	'salty water'
(88)	apsa:lig ho:da	'father went to school'
(89)	kᵊpša:lu	'black shawl (blanket)'
(90)	kᵊphaṇa	'black money'
(91)	daplaḷigi	'thick double-sack'
92	praśni	'question'
93	pya:li	'idiot'
(94)	habpa:listyu	'festival passed'
95	habba	'festival'
(96)	habbharti:	'festival (is) grand'
(97)	obtanda	'one man brought'
98	java:bda:ri	'responsibility'
99	labdha	'quotient'
100	abka:ri	'excise'
(101)	habkha:li	'festival (is) empty'
(102)	obguri	'one man——target'
(103)	habja:rtyu	'festival passed'
(104)	obmarta	'one man forget'
(105)	obnᵊdi	'one man——river'
(106)	mᵊbsosi	'dull daughter-in-law'

(107)	hebhuḷi	'big tiger'
108	bramnia	'Creator'
109	bya:ri:	'recent'
110	utpa:ta	'upheaval'
111	sətphala	'good result'
(112)	sutbəḷi	'clean around'
113	atti	'mother–in–law'
114	putthaḷi	'idol'
(115)	satdina	'day (on which someone) died
116	tətka:la	'for the time being'
117	hətgəḍi	'relationship'
(118)	hətjana	'ten people'
119	a:tma	'soul'
120	yatna	'effort'
121	utsa:ha	'enthusiasm'
(122)	matši:ta	'cold again'
(123)	həthuli	'ten tigers'
124	hitla	'backyard'
125	čitra	'picture'
126	tətva	'principle'
127	sətya	'truth'
128	budbuda	'bubble'
129	udbhava	'born of its own accord'
(130)	gudta:na	'(he) beats with fist'
(131)	udtha:nu	'long roll of cloth'
132	udda	'long, length'
133	uddha:ra	'upliftment'
(134)	bidḍabbi	'fallen tin'
(135)	bidkəṇṇu	'fallen eye (sight)'
136	udga:ra	'exclamation'
137	čidghana	'great mind'
(138)	gedjana	'people who won'
139	padma	'lotus'
(140)	udni:ru	'deep water'
(141)	pedsosi	'idiot daughter-in-law'
(142)	bidšagəṇi	'fallen cow dung'
(143)	bidhəllu	'fallen teeth'
144	badli:	'alternative'

145	ədra	'weak'
146	yədva:tədva:	'haphazard'
147	udyo:ga	'occupation'
(148)	soṭbəḷḷi	'zigzag creeper'
(149)	koṭ bya:ga	'(he) gave bag'
150	huṭṭa:	'while being born'
(151)	biṭṭha:li	'left tumbler'
(152)	koṭda:na	'given gift'
(153)	uṭdho:tra	'worn dhoti'
154	aṭṭa	'mezzanine, storey'
155	laṭṭha	'fat'
(156)	nəṭkəḍi	'dig the ground'
(157)	baṭga:li	'round wheel'
(158)	keṭja:ti	'bad generation'
(159)	keṭma:tu	'bad talk'
(160)	koṭṇi:ru	'given water'
(161)	keṭsosi	'bad daughter-in-law'
(162)	keṭ ši:la	'bad character'
(163)	uthəri	'to wear and tear'
164	keṭḷu	'(she) (was) spoilt'
165	bhaṭru	'priests'
166	na:ṭya	'dance'
(167)	aḍbəḍigi	'cross stick'
168	kəḍta	'itch'
(169)	aḍḍa:ri	'cross road, wrong path'
170	uḍḍha:ra	'thread worn around the waist'
171	aḍḍa	'cross'
172	aḍka	'pile (things one on another)'
(173)	giḍga:li	'dwarf wheel'
(174)	ka:ḍji:rgi	'a grain'
175	nəḍməni	'drawing room'
(176)	nəḍṇi:ru	'mid-water'
177	naḍsu	'make walk'
(178)	ha:ḍhagalu	'bright day'
179	voḍḷu	'belly'
180	ku:ḍru	'to sit'
181	oḍya:na	'flight'
182	dikpa:la	'guards of the corners of direction'

183	čakbəndi	'boundary, environment'
184	bhakta	'devotee'
185	həkda:ra	'legal claimant'
(186)	sikdho:tra	'available dhoti'
187	həkku	'right, claim'
188	lekkha	'sum'
(189)	čikga:li	'small wheel'
(190)	sikči:la	'available bag'
(191)	mikjana	'remaining people'
192	čakməki	'lighter (stone)'
193	bikna:si	'vagabond'
194	cikṇi	'tender (with reference to beetlenut)
195	luksa:na	'loss'
196	lakṣa	'lakh, 0.1 million'
197	akša:li	'goldsmith'
(198)	čikhəṇṇu	'small fruit'
199	oklu	'tenant'
200	o:kḷi	'coloured water'
201	bhakri	'round thin bread made of jowar'
202	pəkva	'ripe'
203	šakya	'possible'
(204)	digbala	'strength from directions'
205	ho:gti:ni	'(I) go'
(206)	mu:gdha:ra	'thread through the nose (of an animal)
(207)	nugkitta	('he) uprooted plenty (of plants)
208	magga	'loom'
(209)	həčbya:ḍa	'don't apply'
210	kəčta:na	'(he) bites'
211	həčda	'(he) applied'
212	hačḍa	'ragged cloth'
213	pička:ri	'syringe'
214	hačči	'tatoo'
215	əččha:	'pampering'
(216)	bičhəri	'open (and) tear'

217	kəčya:ḍu	'to quarrel'
218	hejja	'hole for ear ring and nose ring'
(219)	ajhuli	'very big and old tiger'
220	vajra	'diamond'
221	ajva:na	'a seed'
222	jya:sti	'excess'
223	kəmpu	'flavour'
224	imbu	'scope'
225	ḍambha	'pride'
226	kamta	'animal husbandry'
(227)	tamdana	'their cattle'
(228)	tamdhana	'their wealth'
229	tamṭi	'drum'
230	amṭhi	'broth'
231	damḍi	'a coin'
(232)	nimkuri	'your sheep'
233	jamkhani	'carpet'
(234)	namguḍi	'our temple'
235	čamča	'spoon'
(236)	nimčhətri	'your umbrella'
(237)	samjo:ḍi	'equal'
238	amma	'grand-mother'
(239)	sumniru	'keep quiet'
240	thamṇi	'peace'
(241)	nimsa:ri	'your turn'
(242)	nimšakti	'your strength'
(243)	nimhaṅga	'like you'
244	a:mla	'acid'
245	ta:mra	'copper'
246	mya:le	'on, above'
(247)	janbala	'support of people'
(248)	tanbha:ra	'his own weight'
249	tənti	'wire'
250	antha:	'like that'
251	anda	'beauty'
252	andha	'blind'
253	tanka	'until'
(254)	tankho:li	'his own room'
(255)	tangəti	'his own codition'

(256)	tanča:ḷi	'his habit'
(257)	tanja:ti	'his caste'
258	sənma:na	'honour'
259	tanna	'his, his own'
(260)	tansa:li	'his school'
(261)	tanši:la	'his character'
(262)	honhoḷi	'flow of gold'
(263)	tanli:la:	'his own play'
(264)	tanro:ga	'his disease'
265	janva:ra	'holy thread'
266	nya:ya	'justice, quarrel'
(267)	kəṇbala	'power of the eye'
(268)	heṇbha:ra	'very heavy (like corpse)'
(269)	saṇtana	'smallness'
(270)	kəṇḍəṇi	'till eyes get tired'
271	aṇṭu	'glue'
272	kaṇṭha	'neck'
273	kəṇḍu	'having seen'
274	kəṇkəṭṭu	'magic'
(275)	kəṇguḍḍi	'eye ball'
(276)	saṇməni	'small house'
277	saṇṇa	'small'
(278)	baṇsəri	'colour——right'
(279)	guṇša:li	'righteous'
(280)	heṇhaḍi	'give birth to a female child'
281	puṇya	'merit'
282	suṅka	'tax'
283	paṅkha:	'fan'
284	aṅgai	'plam'
285	səṅgha	'association'
286	va:ṅmaya	'literature'
287	va:ṅniščaya	'oral decision'
288	spandana	'movement'
289	a:sti	'property'
290	əsthi	'bone'
291	vəyaska	'adult'
292	bhəsma	'ash'
293	sna:na	'bath'
294	nissəha:ya	'helpless'

295	əsli:	'genuine'
296	səhəsra	'thousand'
297	sva:rtha	'selfishness'
298	la:sya	'a form of dance'
299	puṣpa	'flower'
300	puṣṭa	'well bred'
301	puskəḷa	'abundant'
302	puṣya	'10th month of Indian calender'
303	pušti:	'strength'
304	niščaya	'decision'
305	re:šmi	'silk'
306	niššakti	'weakness'
307	əšli:la	'obscene'
308	a:šraya	'shelter'
309	višva:sa	'faith'
310	šya:ma	'black'
311	səhsa:	'suddenly'
312	hrasva	'short'
313	ba:hya	'outward'
314	solpa	'little'
(315)	albərli	'let (him, her, it, them) come'
316	so:lta:na	'(he) gets defeated'
317	ka:ldaḷa	'infantry'
(318)	ka:lkasa	'insignificant (thing)
(319)	həlgiri	'pen teeth'
(320)	həlčəḷi	'teeth set on edge'
321	jalma	'life'
322	kelsa	'work'
(323)	kəlhoḍi	'throw stone'
324	alla	'not'
325	həlva:	'a sweet dish'
326	kəlya:ṇa	'marriage'
327	ṣərpa	'snake'
328	arbha:ṭa	'grand'
329	sərti:	'turn'
330	gərdi:	'grand'
331	nirdha:ra	'decision'
332	karka	'fourth zodiac'
333	durgati	'bad state'

334	durghaṭana	'accident'
335	čarča:	'discussion'
336	gərju	'necessity'
337	karma	'deed'
338	karṇa	'a personal name'
339	varṣa	'year'
340	arha	'deserving'
341	barlu	'broom'
342	bərri	'(you) come'
343	pərva	'festival'
344	ka:rya	'work'
345	avsara	'haste'
346	gəvhara	'cave'
347	avləkki	'beaten rice'
348	avḷu	'she'
349	avru	'they (epicene)'
350	avva	'mother'
351	vya:pa:ra	'business'
352	sa:ybəḍi	'beat to kill'
353	sa:yta:na	'(he) dies'
354	pha:yde	'profit'
(355)	kəyka:lu	'hand and feet'
356	pa:ykha:ni	'lavatory'
357	kəygətti	'hand sword'
(358)	ta:yna:ḍu	'motherland'
359	kəyya:re	'with own hands'

It is interesting to note that out of 1089 possiblities of geminations and clusters only 290 occur in Kannada. Out of these 290 occurrences 110 are with word juncture in between and the other 180 are without word juncture.

Vowels : There are twelve vowel phonemes—six short and six correspondingly long—in the dialect under description.

	Front	Central	Back
	Unrounded	Unrounded	rounded
High	i i:		u u:
Mid	e e:	ə ə:	o o:
Low		a a:	

Nasalization occurs on vowels to contrast the meaning. Hence nasalization is also a phoneme / ∽ /.

Contrasting minimal pairs for length of vowels :

360 kiḍi 'spark'
361 ki:ḍi 'insect'
362 keḍu 'to spoil'
363 ke:ḍu 'loss'
364 bari 'to write'
365 ba:ri 'turn'
366 hogu 'to enter'
367 ho:gu 'to go'
368 kuri 'sheep'
369 ku:ri 'a parasite on body'
370 əṣṭu 'that much'
371 ə:ṣṭu 'all that much'

Contrasting minimal and analogous pairs for nasalization.

372 ka:vu 'heat'
373 kã:vu 'handle'
374 sa:vu 'death'
375 sã:vi 'a kind of grain'

Allophones : Some of the vowels show a deviation from their cardinal position, as indicated in the chart, under phonologically definable conditions. They are listed I below.

/i/ [I] a lower variety of high front unrounded vowel when followed by word juncture (i. e. the final position)

376 ili 'mouse'
377 kəli 'to learn'

[i] high front unrounded vowel, occurs elsewhere.

378 kiḍi 'spark'
379 kuri 'sheep'

/e/ [E] a lower variety of mid front unrounded vowel, occurs before word juncture.

380 ele 'leaf'
381 beḷe 'crop'

[e] mid front unrounded variety occurs elsewhere.

382 keḍu 'to spoil'
383 mede 'heap'

/a/ [ʌ] a low mid back unrounded vowel, occurs before a gemminated voiceless velar stop.

384 akka 'elder sister'
385 pakka 'genuine, definite'

[A] low central unrounded vowel, occurs before word juncture,

386 kamala 'lotus'
387 jagaḷa 'quarrel'

[ạ] shorter variety of low central unrounded vowel, occurs in the penultimate position of a vowel in the words containing 3 or more syllables.

388 bi:garu 'relatives'
389 makkaḷu 'children'
390 ivattu 'to-day'
391 attatta 'yonder'

[a] slightly higher variety of low central unrounded vowel occurs elsewhere.

392 avanu 'he'
393 appa 'father'

/o/ [ɔ] low-mid back rounded vowel occurs when followed by a syllable containing a vowel other than [o] or [u].

394 mola 'rabbit'
395 kori 'to drill'

[o] high mid back rounded vowel occurs elsewhere.

396 koḍu 'to give'
397 toḍu 'to wear'

/u/ [u̠] a slightly unrounded variety occurs before word juncture.

398 adu 'it'
399 məḍu 'pond'

[ụ] shorter variety of high back rounded vowel occurs in the penultimate syllable, when the vowel in the ultimate syllable is [u]

400 tukku 'rust'
401 sustu 'delay'

[u] high back rounded vowel occurs elsewhere.

402 kusti 'wrestling'
403 urusu 'Muslim festival'

/ə/ mid central unrounded vowel occurs in the nonfinal syllable of a word.

404 kəri 'to fry'
405 təgəli 'a lady who is a lier'

The long vowels more or less maintain their cardinal position in all the places of their occurrence. Hence no distinction on the basis of auditory phonetics has been made.

The distribution of vowel phonemes :

The occurrence of vowels in the initial, medial and final positions has been shown in the following table. Since a number of examples have already been given to show their occurrence, additional examples are not given here.

Vowel	Initial	Medial	Final
i	376	37	56,66,254
i:	34	19,54,63	28
e	380	162	30.380,381
e:		28	
a	2,8,12	20	13, 14, 18
a:	14,308	55,61,67	62, 250
o	97,102,104	148,149,179	
o:	200,18,22	205	
u	87,129,132	62,128,207	60, 64, 65
u:	68	64.206	
ə	145,295,370	1,11,59	
ə:	371		

The numbers in the chart refer to the numbered examples cited earlier. A blank indicates the impossibility of occurrence or the nonavailability at the moment. However /e:/ seems to appear in the initial position. But it always occurs with an onset of /y/. Hence they were treated only as medial occurrencs. /ə:/ occurs medially in my speech. But in view of its extremely rare occurrence and the uncertainty of its occurrence in other speakers, it is ignored.

CHAPTER 2

Oscillographic Analysis

2. 1 The Equipment :

All the 405 illustrations, in the sequence as they appear in chapter 1, were tape recorded in a reverberation controlled room, on Mez-28 tape deck at 7½ inches per second (19 cms) speed, on full band, pronouncing each item once. They were pronounced as they would be in normal or continuous speech. As there are single words, compound words, phrases, parts of the sentences and a few full sentences, in the data, sufficient care was taken to maintain their respective intonation. The ideal way would have been to splice out the required item from the natural speech. But in view of the paucity of time, this was met out by exercising care. Yet the possibility of deviation in the intonation, which might affect the duration, intensity and pitch, cannot he ruled out.

The recorded tape was played back at the recorded speed and fed to a H-102 Oscillograph through the frequency distributor. The Frequency Distributor separates the frequencies of the glottal tone from the resonated frequecncies in the resonance chambers-i.e. the supraglottal and nasal cavities. Thus the oscillograph traced the complex waves of glottal tone in the lowest portion of the 35mm film and the complex waves of resonated tone in the middle portion of the film. On the top, the signals from the timer marked the time of speech, at an interval of 10 milliseconds.

The H-102 oscillograph which was pressed into service has four speeds of film movement : 25 mm, 50 mm, 100mm and 250 mm per second. The present films were taken setting the machine at the film speed of 250mm/second. At this rate, the film should run 5 mm in 20 milliseconds. But by measurement of the timing on the film, it was found that the film had actually run 5mm in 19 milliseconds. This means

that the film in the oscillograph was running at an actual speed of 263.17 mm per second. However this discrepancy was not of coucern in the analysis because the extra speed of film movement by 13.17 mm per second affected the time markings and the oscillograms simultaneously. Hence the relationship between the time of speech and the oscillograms does not get affected. Only that the film would have moved 5.27 percent more than what it would have done under the assured speed.

The following pictures illustrate some of the oscillograms. The characteristics of the sounds are visually distinguishable.

2.2. Segmentation of oscillograms

About 200 meters of 35 mm film was analysed by demarcating the boundaries of each sound segment.

The oscillogram of an utterance was preceded and/or followed by some acoustic noise signal. These were ignored and the actual commencement and the termination of sound signals were demarcated. The aspiration of consonants and the affrication of affricates were also segmented in order to study their relationship with the preceding sounds. It was not possible to demarcate the commencement of voiceless stops in the initial position of an utterance. But their plosion or burst was clearly visible as in the case of their medial occurrence. After the plosion or burst there was a time lag of 10-35 milliseconds (see section 2.8 for details) for the vowel to follow. In these cases the boundary was marked including the time lag, that is, at the actual commencement of the vowel.

Whenever the vowel was emphasised, the usual sharp declining heights of each damped wave were raised up, making the usually dark central portion light. Since the total number of periods remained the same, this feature remained unaccounted for. This would be possible only by the harmonic analysis. Since the harmonic analysis was not possible, the distinction of such vowels from the others could not be brought out.

Many clusters, with or without word juncture, showed a vowel release [a] or [ə] in between. Such releases were also segmented The total loss of the penultimate vowel of a word,

resulted into a cluster of the neighbouring consonants. In the process of this loss an extra short vowel was remaining, sometimes.

A few problems were encountered in the segmentation. The boundaries in the sequences of [al] [aḷ] [av] [ay] and [a:l] [a:ḷ] [a:v] [a:y] could not be precisely demarcated in all the cases. By comparing [a:l] with [i:l] and [la:] etc., the boundaries were determined. In some other cases, the waves were partially or completely overlapping. For example [h] and [v] ; [h] and [a]. The aspiration and affrication also had sometimes overlapping waves. In cases of partial overlapping, the durationof overlapped portion was added to the duration of clear portions of both. In cases of complete overlapping, the duration was counted in both.

Though the boundaries between consonant clusters could be demarcated in many cases, it was not possible in a few, eg. [pt] or [bd]. In such cases also it was determined by cross reference.

2. 3 Plan of plotting the duration

The durations in milliseconds, of each vowel and consonant were plotted as follows.

(A) Vowels : Thc vowels were plotted under three columns : Initial, Medial and Final. Whenever the duration of a particular occurrence was markedly long or short, they were circled out for verification of transcription, by listening to the tape. Those vowels which gave an anditory impression that they were long or short, were transferred to the respective columns. But those vowels which did not give such an impression were retained in the columns and the reasons for their shortness or length, was sought in terms of phonetic contexts.

All the figures in each column were totalled and the average absolute duration was calculated. the durations of vowels under the definable phonetic contexts were separately totalled and averaged to arrive at their relative duration. It is believed that the probable idiosyncrasies of pronunciation would be nullified or reduced to a negligible minimum in the process of averaging.

(B) Consonants : The consonants were plotted under six columns: (1) Initial (CV) (2) Medial (VCV) (3) in Cluster (C_1C_2) (4) in Cluster with word juncture in between ($C_1 \neq C_2$) (5) in Gemination (C_1C_1)and (6)before Aspiration (Ch). The consonants betrayed a marked difference in duration when they occurred before aspiration and in cluster with [h̃] with word juncture. for example : kapha 'phlegm' and kaphaṇa 'black money'. The former is a case of aspiration and the latter a seqnence with word juncture. Under column numbers 3 and 4 the figures were indicated by a preceding or following hyphen whenever the figure referred to respectively the second or the first member of the cluster. This was done with a view to calculate the duration when the consonant occured as the first or the second member of a cluster. In cases of unsegmentable sequences like [pt] or [bd] the total duration was halved in those cases where cross reference was not possible. This was only a via media where the total duration fell much below the sum of the average durations shown by the respective consonants elsewherc. It was believed that the differnce that might arise by halving would be reduced to a negligible minimum in the process of averaging.

In case of completely overlapping waves, the duration was entered under each of their components on verification that their duration approximately corresponded with that of their clear waves. In cases of partial overlapping, the everlapped portion was added to their clear portions.

The vowel releases in between thc clusters were not counted mainly because of their uncertain quality—whether [a] or [ə] could not be decided. However, this feature has been accounted for in the observations. The vowels which showed an exteremely short duration in the penultimate position were counted, as there was certainty about their quality.

The aspiration of consonants was counted separately under [h] because it was acoustically justifiable that the noise patterns of aspiration and [h] were the same.

The duration of stop and affrication before aspiration were counted along with their other occurrences in order to arrive at their absolute duration. They were separately counted later in order to arrive at their relative duration before aspiration.

		CV			VCV			C_1C_2						
								C_1			C_2			
		Dur	Int	Freq	Dur	Int	Freq	Dur	Int	Freq	Dur	Int	Freq	Du
Plosives	p	—			107.50			97.00			125.66			109.7
	b	78.43			62.50			65.00			55.20			107.1
	t	—			106.50			124.70			123.00			120.1
	d	70.16			56.43			84.44			63.36			105.0
	k	—			107.25			115.40			96.84			129.6
	g	83.33			56.78			53.07			49.33			70.33
	ṭ	—			82.00			135.75			119.43			104.77
	ḍ	66.00			33.90			58.33			30.33			50.37
Affricates	č St	—			79.00			93.00			79.40			91.75
	č Af	40.33	6		51.66	4.5		35.00	3.5		44.80	5		49.00
	j St	65.40			58.00			69.33			60.00			55.00
	j Af	23.70	2.5		31.25	5		27.66	3		60.00	3		32.00
Fricatives	h	46.84	0.5		44.20	2		67.00	3					
	s	86.61	2.5		101.33	2.5		97.13	3		104.75	3		
	š	86.00	6.5		142.33	5.5		109.00	6.5		102.00	6.5		
	ṣ				98.00	5		71.83	5		80.00	6		
Nasals	m	42.25	2.5	125.00	54.66	6	133.33	86.53	6	141.17	50.00	3	120.00	91.77
	n	45.17	4	171.42	46.80	5.5	150.00	74.77	3.5	106.66	58.16	4.5	127.68	88.88
	ṇ				55.80	8	125.22	100.80	6	178.94	52.33	5	133.33	85.90
	ṅ							92.85	5	133.33				
Liquids	l	61.77	3.5	100.00	53.90	6	118.47	74.00	5	107.69	57.44	5	137.74	84.66
	ḷ				48.33	8	109.10	81.00	8	107.23	46.33	4.5	125.00	
	r	49.50	4	117.62	20.30	1	133.33	31.19	1.5	150.00	31.69	4	125.00	
Semi Vowels	v	53.90	6	100.00	60.07	6	111.11	68.00	8	100.00	60.50	6	120.69	
	y	43.33	3	104.17	65.44	8	116.66	50.00	6.5	120.00	48.88	4.5	125.00	63.60

Dur—Duration in milliseconds ; Int—Intensity in millimeters ; Freq—Frequency in cycles per second ; St—Stop portion ; A

$C_1 \neq C_2$												
C_1		C_2			C_1C_1			Ch			Aspiration	
Int	Freq	Dur	Int	Freq	Dur	Int	Freq	Dur	Int	Freq	Dur	Int
		107.00			198.00			45.00			35.00	3
		58.93			152.80			56.09			50.07	5
		115.43			165.50			103.66			49.00	2
		63.57			147.00			53.63			49.16	7
		103.63			190.57			80.28			60.20	3
		88.00			132.00			50.16			33.00	3
					169.40			83.75			48.40	1.5
		70.00			135.00			42.50			60.00	7
		67.50			140.00			70.00				
		38.66	4		65.00	5.5		40.00	5		23.80	5
		69.33			120.00			45.00				
		31.50	2		37.00	3		25.00	4		28.33	4
		56.69	5									
		108.00	3		150.00	3						
		127.16	6.5		153.00	6						
.5	116.66	62.50	5	146.34	117.50	6	144.06					
	130.71	69.00	6	150.00	128.00	6	132.81					
	142.85	75.00	5	118.42	89.33	5	123.07					
5	111.11	92.50	7	154.76	15.00	6	106.66					
					63.00	7.5	123.07					
		35.00	1	136.86								
					75.00	6	123.52					
5	142.85	30.00	8	833.33	120.00	7	180.00					

fricate portion.

The affricates were plotted in two parts: the stop portion and their affrication. It was done so because the affricates in gemmination revealed interesting relationship between their stop and affrication portions.

All the figures in duration and frequency were taken only up to two places after decimal. Further fractions were ignored. Intensity is measured only in fractions 0.5 millimeter.

2.4 Measurement of Intensity

Intensity is the acoustic power which is measured in watts. With reference to perception, they are computed in terms of decibels.[7] But on the basis of oscillograms neither of the measurements was possible. Thus an easier way of expressing the variation in intensity of vowels, nasals, semivowels and liquids in various positions of their occurrences was to measure the height of the highest period or peak from the central line, in millimeters (i.e. only the positive side). This gives a visual discrimination of the periods in the oscillograms. The contours of peaks of the oscillograms of the above mentioned sounds, have been shown in a summary form by taking the average heights of peaks in 1/3rd part of the beginnig, middle and end section of a sound. The contour pictures, given at the end of the results, will give a generalised view about the oscillograms of the sounds.

2.5 Calculation of Frequency

Frequency indicates the number of complete cycles occurring in a second. Hence it is expressed in 'cycles per second' (cps). It varies directly proportional to pitch. That is, higher the pitch, greater the frequency ; lower the pitch lesser the frequenty. The frequency is calculated by the formula[8].

$$f = \frac{1.n}{T}$$

where f is frequency, n is the number of periods and T is tim

7. For detaiis vide Ernst Pulgram: Introduction to Spectrography of Speech. Mouton & Co. 1959. page 26.

8. L.V. Bondarko : *Sound Structure of Contemporary Russian Language,'* (in Russian) Moscow 1977. P. 50-51.

in seconds. Since the time is marked in milliseconds (i.e. 1000 th part of asecond) on the oscillograms the following version of the same fcrmula was used for calculating the frequency of vowels, nasals, liquids and semivowels:

$$f = \frac{\text{no. of periods} \times 1000}{\text{no. of milliseconds}}$$

Ideally the frequency of all sounds in all their occurrences should have been calculated and averaged in vearious posiiions. Thiscould not be done at this stage. The frequency of those sounds whose duration was very near to the average duration was calculated. Though it may not follow that the sounds with average duration have the average frequencies also, under the present circumstances it was thought to be a better alternative.

2.6. Results of the analysis

(a) Vowels : The absolute duration in milliseconds, intensity in millimeters and the frequency in cycles per second for 12 vowels in all the three positions have been tabulated in the following table. (p. 26).

(b) Consonants : The results of the duration, intensity and frequency of consonants are tabulated on the next page, in six columns.

The aspiration column which stands outside the main chart has to be read along with [h]. By turning it vertically, the duration and intensity of aspiration of respective plosives and affricates could be shown.

The durations in columns from CV to C_1C_1 are absolute ones. But the durations in column Ch are the relative ones i.e. they show the relative duration of C before aspiration.

In the case of affricates their stop and affrication portions are shown vertically though they appear in sequence. In case of their figures under Ch column it should be noted that the aspiration occurs after affrication, eventhough the duration of stop portion is also affected by aspiration as in the case of plosives.

2.7. Contours of peaks of periods

Vowels : The contours of the peaks of periods are intended to give a relative schematic picture of the oscillograms of 12 vowels. In the preceding section, the absolute duration and intensity will give a general idea about the distinction of quantity and quality of vowels. But it would be worthwhile to have a little more detailed perspective. With this intention the height of each period (peak) of oscillogram was measured. For this purpose only those vowels whose duration was very near to the absolute ones, were taken, in all positions of their occurrence.

The total number of peaks were divided into three parts : (1) Beginning (2) Middle and (3) End. The average heights of peaks in each of these parts were calculated. The average heights are plotted on graphs on the following pages. The heights are plotted along Y axis. The absolute durations are plotted along X axis.

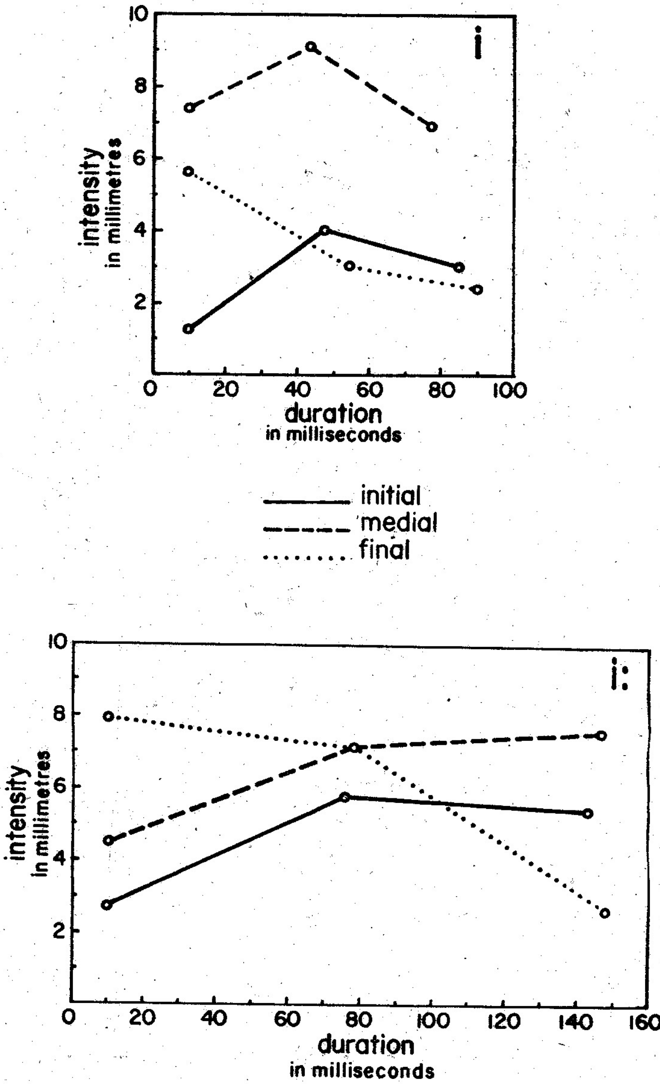
Contours of nasals, liquids and semivowels

Though it was possible to draw the contours of these sounds, it has not been done because their peaks are fairly level in all positions of their occurrence. However l, ḷ, y and v have their maximum intensity when followed and/or preceded by [a] or [a:] whereas the nasals and trill have uniform intensity everywhere.

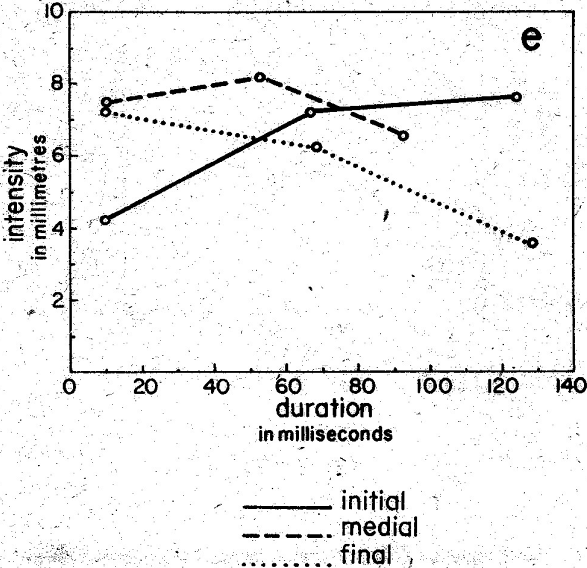
2.8. Observations on the basis of analysis

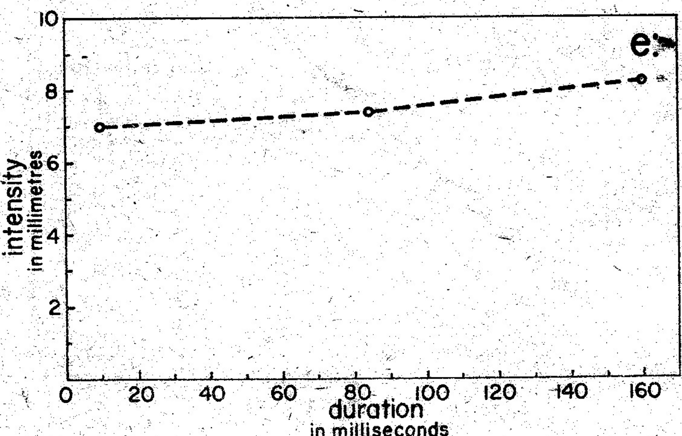
The way that the vowels have been tabulated in the initial, medial and final poitions and the consonants in CV, VCV, C_1C_2, $C_1 \neq C_2$, C_1 C_1 and Ch patterns, presupposes that the duration, intensity and frequency are related to the position of their occur rence. The figures in the tables in the previous section, more or less confirm the presupposition. In other words, the positional classification of vowels and consonants is, in general, ratified by the acoustic characteristics. It means that most of the descriptive conventions are confirmed. However, some of the statements needed modification and about some others an extra information is given.

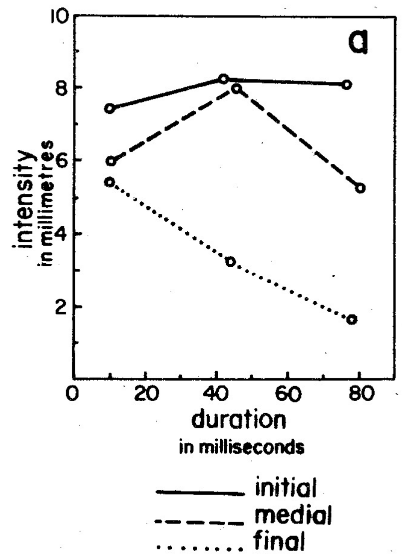
	Initial			Medial			Final		
	Duration	Intensity	Frequency	Duration	Intensity	Frequency	Duration	Intensity	Frequency
i	75.00	6	125.00	60.77	9	120.00	80.81	7	125.00
i:	132.00	7	121.21	136.41	8.5	137.68	138.16	9	114.28
e	114.00	8.5	118.18	83.16	8.5	137.50	118.85	8.5	117.64
e:				151.16	9.5	135.48			
a	67.13	8.5	142.85	71.84	8	128.56	68.54	6	100.00
a:	169.50	8.5	117.64	157.80	8.5	106.25	138.06	8.5	137.68
o	98.00	9	132.65	84.00	8	127.90			
o:	196.66	7	115.78	146.22	7	125.00			
u	64.73	5.5	127.27	58.05	7	136.20	84.98	3	94.12
u:	150.00	6	126.66	168.00	8	142.85			
ə	75.14	5	112.50	64.08	7.5	107.69			
ə:	194.00	9.5	123.71						

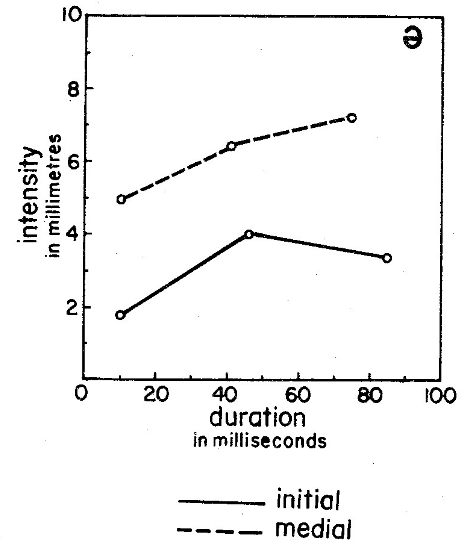


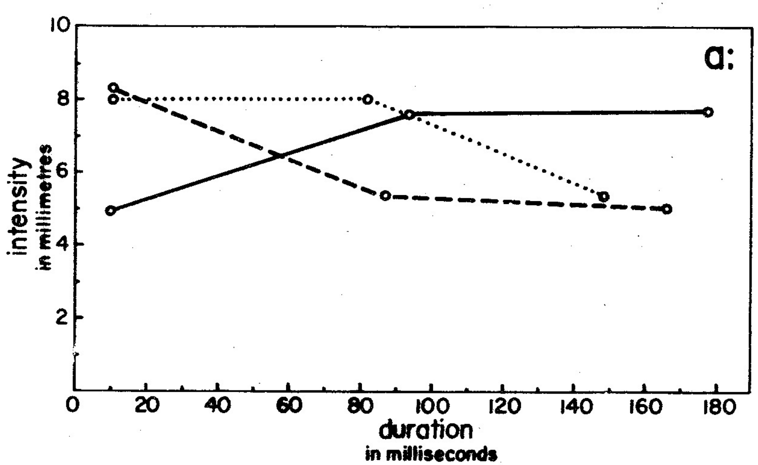
i
intensity
in millimetres
duration
in milliseconds
initial
medial
final
i:
intensity
in millimetres
duration
in milliseconds

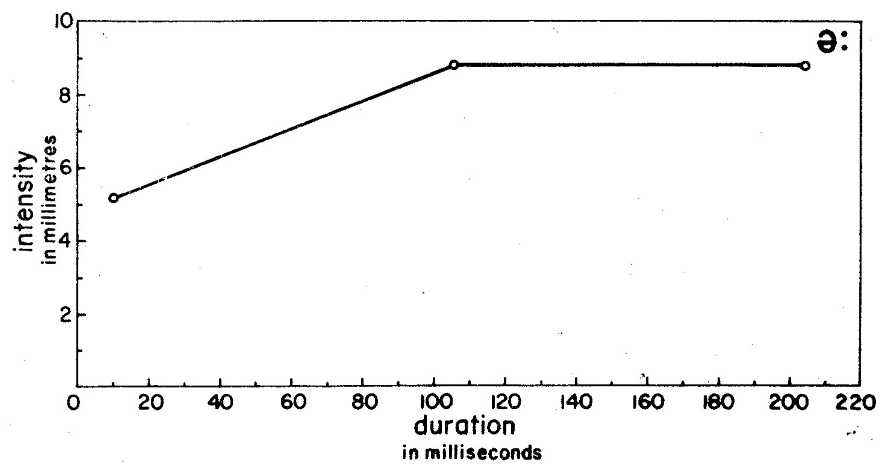

e
intensity
in millimetres
10
8
6
4
2
0
20
40
60
80
100
120
140
duration
in milliseconds
initial
medial
final

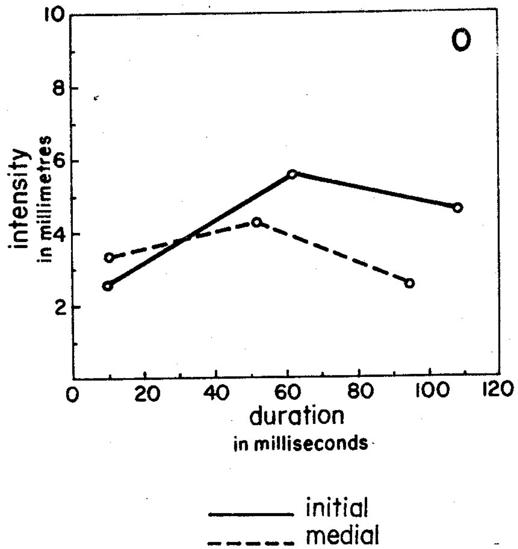

e:
intensity
in millimetres
10
8
6
4
2
0
20
40
60
80
100
120
140
160
duration
in milliseconds

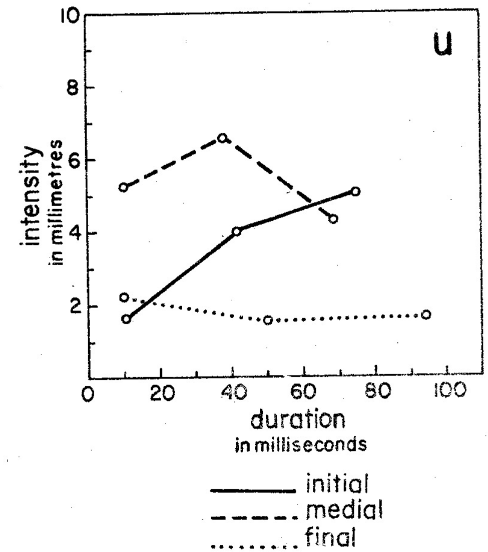

a
intensity
in millimetres
duration
in milliseconds
initial
medial
final

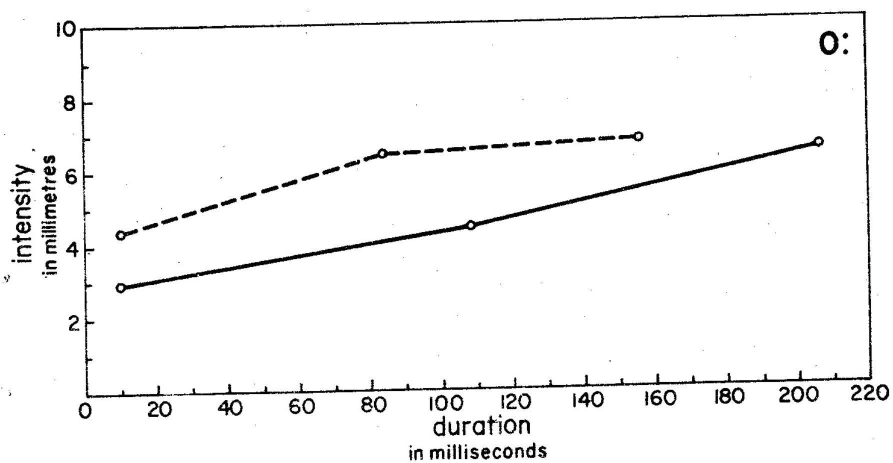

ə
intensity
in millimetres
duration
in milliseconds
initial
medial

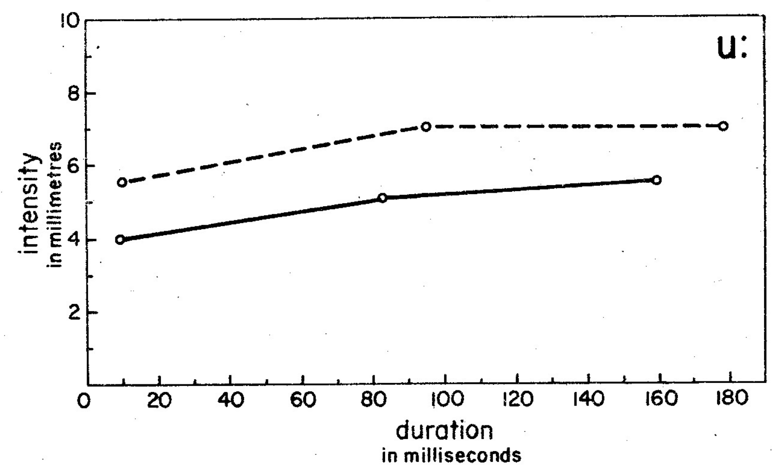

a:
intensity
in millimetres
duration
in milliseconds


ə:
intensity
in millimetres
duration
in milliseconds


o
intensity
in millimetres
duration
in milliseconds
initial
medial

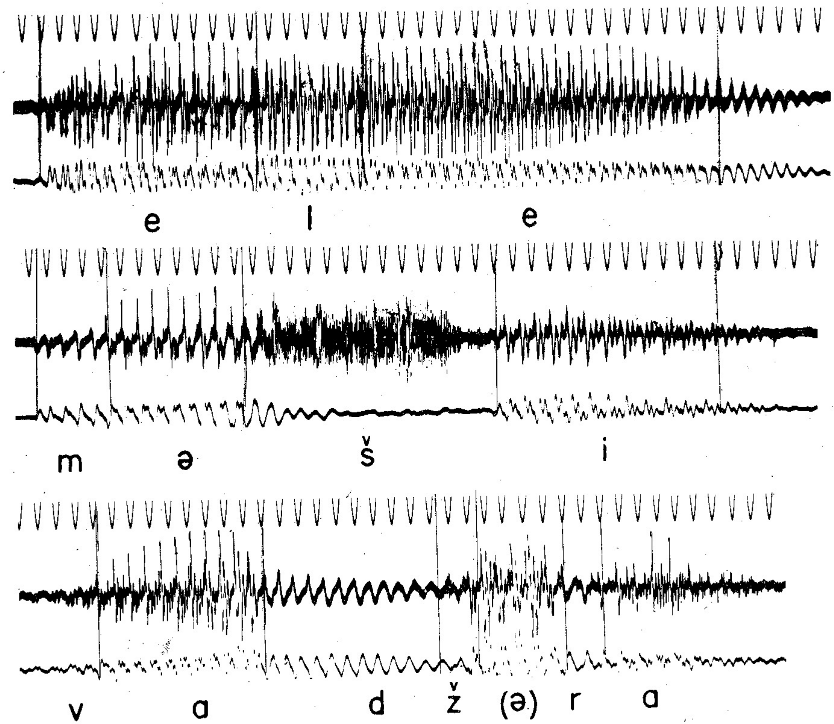

u
intensity
in millimetres
duration
in milliseconds
initial
medial
final

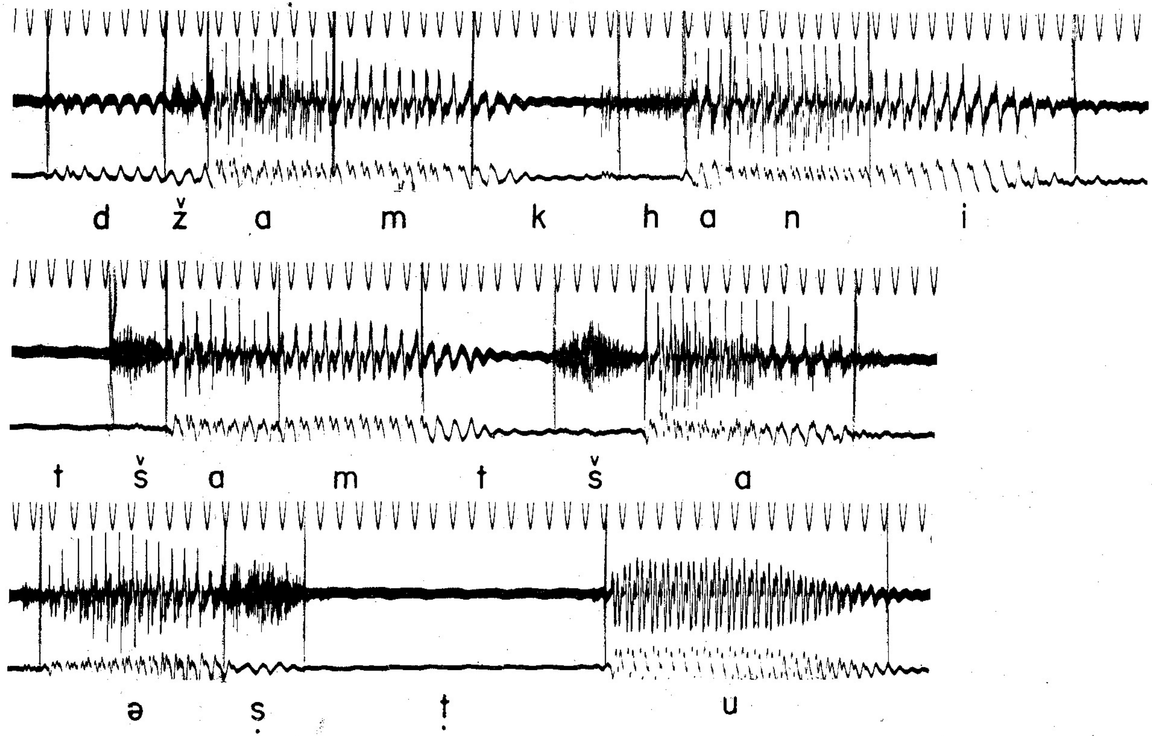

o:
intensity
in millimetres
duration
in milliseconds

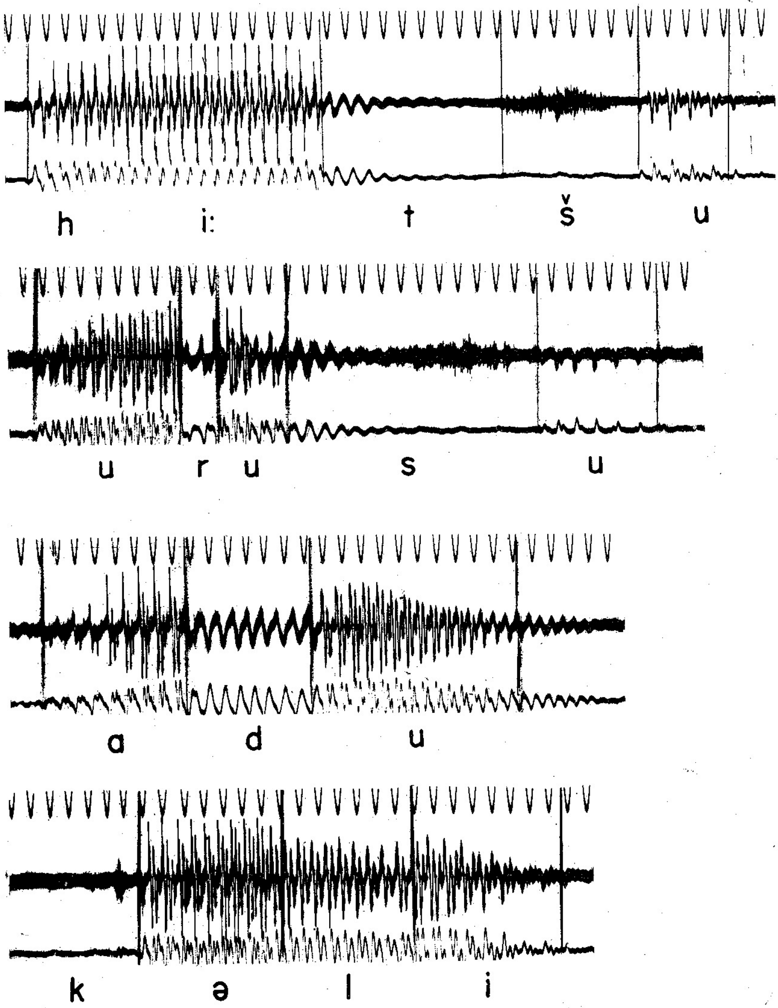

u:
intensity
in millimetres
duration
in milliseconds

Note : The contour pictures of the peaks of the periods on the preceding 6 pages need to be explained. The three small circles on the picture of each vowel indicate the average heights of the peaks in the beginning, middle and the end part of the oscillograms. The average duration of each vowel, in all the three positions, can be made out from the base line. Thus each picture shows the relative duration of each vowel in the initial, medial and final positions. This would give an idea about the wave form of all the vowels in all the positions. As the pictures are drawn with a uniform scale, one would get an idea about the relative duration of each vowel—especially short vs long vowels—and the relative heights of the peaks of the periods in the beginning, middle and end portions.

The real size photographs of the oscillograms on the following pages, will illustrate the oscillograms of some of the words. The line of segmentation can also be seen there. The characteristic features of sounds can be noted there.


e l e
m ə š i
v a d ž (ə) r a


d ž a m k h a n i
t š a m t š a
ə ṣ ṭ u


h i: t š u
u r u s u
a d u
k ə l i

All the observations made, while analysing the oscillograms could not be accommodated in the tables. They are noted below, along with the ones that are explicit from the tables.

Vowels : The long vowels showed 180–230 percent duration when compared with their short counterparts. The short vowels showed 50–70% more duration in the final position than their initial position when the vowel in the penultimate syllable was short. This was true even when the penultimate vowel was extra short due to the tendancy of loss or when there was a total loss. When the vowel in the penultimate syllable was long the duration of final vowel was almost the same as in its initial position.

Most of the vowels showed their highest intensity in the medial position. The vowels, when followed and/or preceded by a nasal, liquid or a semivowel, showed highest intensity than when followed or preceded by a plosive or an affricate. In most cases the vowels showed their minimum intensity when followed and preceded by a voiceless consonant.

In the final position the vowels showed a fast declining intensity-sometimes only 1 or 2 millimeters. This means that the vowels tend to be voiceless in the final position.

On the basis of intensity and frequency, it is not possible to verify the tongue height or the degree of lip rounding. Even though initially high vowels show lesser intensity than the low vowels, it is not the case medially. Medially, [i e a] showed descending intensity and [u o a] showed ascending intensity. Since intensity is related to loudness it is better not to read any meaning in the partial regularity.

The short varieties of [a] and [u] in the penultimate position were attested by their shortness in duration.

The frequency of [o], followed by [i], [o] or [u] in the next syllable was about 140 cps. Whereas when it was followed by [a] in the next syllable it was 115 cps. On the basis of this evidence there would be a temptation to suggest a modification to the allopnonic statement about [ɔ]. "[ɔ] occurs only when followed by [a] in the next syllable".

The feature of loss of penultimate vowel is applicable only to short vowels in a single word, which contain 3 syllables

(Examples with more than 3 syllables, in comparable environments, were not taken). The loss was more expected when the first of the three vowels was long and the others were short. In many cases there was a total loss. But in some cases an extra short variety of 30-60 percent of their normal duration was retained.

Consonants : The total number of consonants was reduced to 23 from 33, because the aspiration of 10 consonants was segmented.

Though it was not possible to characterise the voiceless stops, the occlusion and the time taken for the vowel to follow after the burst were characteristic. They were fairly regular as shown in thc following table. Intensity of burst depended upon the hardness of closure.

	Time taken for occlusion	Time for the vowel to follow the burst	Intensity of burst
P	30	20	0.5
t	35	25	3
ṭ	10	10	1.75
k	20	30	2

The voiced pioslves were noι showing the occlusion or burst. But they showed the glottal tone i.e. voicing. Medially they/were fricatives whose intensity and frequency could be measured. Their average intensities and frequency are noted below:

	Intensity	Frequency
b	2	100
d	3	166.66
ḍ	2.5	142.85
g	3.5	150

The duaation of consonants in the medial position is less than in their initial position. The duration in the medial

position is almost equal to the duration of C_1 in $C_1 C_2$ pattern whereas in most cases the duration of C_1 in both $C_1 C_2$ and $C_1 \neq C_2$ was more than the duration of their respective C_2.

The duration of consonants before aspiration is 25–60 per cent less than their duration elsewhere.

In case of /ḍ/ its duration in VCV is less than that in CV. This attests that in VCV it is a flap. Also its C_1 duration in $C_1 C_2$ and $C_1 \neq C_2$ was more. This suggests an amendment to the phonemic statement : " [ḍ], a voiced retroflex, flap occurs between vowels and in $C_1 C_2$ and $C_1 \neq C_2$ patterns and in C_2 of $C_1 C_2$ pattern".

/g/ and /d/ have lesser duration between vowels. They also show lesser duration in C_2 of $C_1 C_2$ pattern indicating that they are fricatives. Hence an amendment to the phonemic statement may be suggested : "[g̱] and [ḏ] voiced velar and dental fricatives occur between vowels and in C_2 of $C_1 C_2$ pattern".

/b/ also shows similar tendency in the same position. Hence a statement may be added under /b/ : "[ḇ] a voiced bilabial fricative occurs between vowels and in C_2 of $C_1 C_2$ pattern".

These amendments and additions are made on the basis of the tendency shown by the durations. They are to be subjected to further tests in auditory phonetics.

The duration of a single voiceless stop after [r] is nearly double or more than double–their initial or medial duration.

The duration of geminate consonants is 150–230 per cent when compared with their duration in the initial or medial positions.

The affrication of affricates is also a noise very similar to that of fricatives. But they have approximately 50 per cent or less of the duration of the fricatives. That is why the affricates were not segmented into stops and fricatives, as it was done in case of aspirated consonants. Aspiration was segmented because the duration of aspiration and [h] elsewhere showed almost equal duration. The affrication of [j] showed the noise of [š] with the glottal tone. Though the periods were fairly regular it was difficult to count them for the calculation of frequency.

The distinction between palatal affricate [č] and the dental affricate [c] is clearly shown by the intensity of affrication. The former has more intensity than the latter–comparable to the intensities of [š] and [s] respectively.

The noise pattern of [h] in various positions and that of aspiration are the same. But the aspiration of voiced consonants is, sometimes, accompanied by the glottal tone, making it [h] a voiced glottal fricative. Since it was not observed in all the cases of voiced aspirated plosives, it has not been accounted as an additional allophone.

The intensity of [š] is the highest and that of [s] the lowest. In between is the intensity of [ṣ]. Because of their highly complex nature, they remain as noises withou precise frequency.

As has already been indicated while discussing the contours, the nasals have farily level heights of peaks of intensity in the medial positions. But in the initial position they show a little less intensity in the first one or two periods.

The liquids and semivowels (except [r]) show almost equal intensity to the following or preceding vowels. Many times, this rendered it difficult to draw the boundary lines between them. But in the initial position they have generally lesser intensity.

The effect of juncture is clearly visible at least in two cases : (1) the duration of C_1 in $C_1 \neq C_2$ is longer than C_2. (2) [ḍ] in C_2 of $C_1 \neq C_2$ is equal to or more than its duration in the initial position. This suggested that [ḍ] is a plosive in C_2 of $C_1 \neq C_2$.

Though [ṇ] does not occur in the initial position it occurred in C_2 of $C_1 \neq C_2$ due to morphophonemic change: koṭ + ni:ru > koṭ ≠ ṇi:ru 'given water.'

There is a vowel release of 25–45 milliseconds' duration between C_1 C_2 and $C_1 \neq C_2$. Its waves resemble those of [a] and [ə]. Since it was not possible to determine the tongue height, it remained undeciphered.

Supra-segmental modifications

Nasalization is difficult to be characterised on the basis of intensity and frequency. Nasalization showed the composition of waves with higher amplitudes than the non-nasalised vowels. Since it was not possible to do the harmonic analysis, the nasalization could not be characterised.

Some of the observations made above may seem to be over–generalizations. Too much of meaning might have been read in the oscillograms. But the observations do open up new areas for further investigation. However it has been seriously examined, to what extent the oscillographic analysis can help the phonemic description of the language.

CHAPTER 3

Spectrographic Analysis

3.1 Sound spectrograph

The oscillographic analysis in the preceding chapter has been able to show the duration, intensity and frequency of the sounds. The observations made in the section 2.8 bring out the limitations of the oscillographic analysis. The spectrographic analysis, on the other hand, gives a better insight about the nature of sounds.

The sound spectrograph is a good apparatus to study the distribution of acoustic energy over a frequency range from 100 to 10,000 c/s. Thus it is possible to determine the quality of vowels accurately.

The spectrograph, which is used for taking the spectrograms, filters the frequency range from 0 10,000 cycles through 48 channels. Each channel filters the frequencies around its

Channels		Difference in filtering range c/s
1– 2		50
2–14	between each consecutive channels	75
14–23	,, ,, ,,	100
23–37	,, ,, ,,	150
37–38		350
38–39		400
39–40		450
40–43	between each consecutive channels	500
43–44		550
44–45		600
45–46		400
46–47		800
47–48		600

central range. This range goes on progressively widening from channel 1 to channel 48. Channel No. 1 filters the frequencies around 100 c/s. The channel No. 2 filters the frequencies around 150 c/s. That is, the difference in the filtering ranges between channel Nos. 1 and 2 is 50 c/s. Thus channel No. 48 filters the frequencies around 9,700 c/s. The preceding table shows the difference in the filtering ranges of 48 channels.[9] It may be understood that the difference in the filtering range of each consecutive channel is as shown in the difference column. E.g., channels 2 & 3, 3 & 4, etc., up to 14 have the difference of 75 c/s each. Similarly in other cases also.

The acoustic energy present at various frequencies is marked in spots of varying degrees of darkness by these 48 channels on 35mm film. The time is also marked by the vertical lines at an interval of 100 milliseconds. Between any two vertical lines there are 25 spots. It means that each successive spot indicates the duration of 4 milliseconds. Thus it is possible to measure the duration of each sound in multiples of 4 milliseconds.

The spectrograms show the time and frequency in greater detail. The speed of the film movement in the camera must be 90 millimeters per second. This could be inferred on the basis of the films which showed 9 millimeters length of film for 100 milliseconds.

On 35mm film, the space available for the spectrograms is 24 millimeters. The space of 11mm is taken by the perforations on both the edges. Thus in each millimeter two channels mark the frequency. Since the first three formants are generally studied for acoustic analysis the space of about 15mm from the bottom line of the spectrograms is important as the first three formants would generally appear within this space. In the top space of 9mm, only the high frequency noises of fricatives and affrication appear.

As the formants are marked in such a small area, it is difficult to make out finer distinctions with bare eyes. Hence the

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9. The figures are taken from the technical data given on '*Sound Spectrograph*' machine.

spectrograms are generally read on 'Readers' which enlarge the spectrograms.

The scale that is used for reading the frequencies of formants is known as the Koenig scale. In this scale the relationship between frequencies upto 1000 c/s is linear and from 1000 to 10,000 c/s it is logarithmic. That is, for example, the distance between 0 and 250 c/s is equal to the distance between 750 and 1000 c/s in terms of number of cycles and it is also equal in terms of space on the scale. But the distance between 1000 c/s and 1500 c/s is equal to 1500 c/s and 2000 c/s in terms of cycles but it is not equal in terms of space on the scale. The latter is less than the former. Thus up to 10,000 c/s the space on the scale goes on becoming less and less. The scale has been so designed because the perceived pitch difference between two frequency levels, higher than 1000 c/s, is logarithmically related.[10]

3.2 Formants : A single energy maximum is called a formant (this definition is from Gunnar Fant). That is, for different sounds (especially the vowels) the maximum acoustic energy is concentrated at different levels of frequency in different shapes and varying degrees of intensity. Both the shape intensity, which is represented by the varying degrees of darkness are important for the acoustic study. The shapes of the formants of vowels depend upon the following and preceding consonants. It requires a little practice to identify the formants. Because, not only the formants but also the harmonics are present on the spectrograms. Generally the harmonics run parallel to the fundamental pitch (F_0) or the frequency of glottal tone. In case of a male voice F_0 will be 100-150 cps. When the F_0 is 100 cps, at 200, 300 and 400 cps etc., (i.e. at the whole number multiples of F_0) the harmonics are likely to appear. The word 'likely' is used because their appearance on the spectrograms depends upon their intensity. The formants are generally darker than the harmonics and they may have rising, level or falling shape, or the combination two or more

10 For details see P. Ladefoged *Elements of Acoustic Phonetics* Univ. of Chicago Press. 1962, pp. 75-79

shapes. Sometimes depending upon the phonetic environment, they may have a bend in the beginning. These characters make the formants distinct from the harmonics. It also requires a little practice to decipher the fused formants. Some part of a formant or the whole of it might fuse with or overlap on another formant. In such cases generally there would be a clue at the end of the formant. That is, the centre of the formant arrows out. The level at the arrow head could be taken as the centre of the formant. This situation was often present in F_1 and F_2 of final [u].

Generally the first three formants are relevant for the acoustic study. In cases of vowels with greater intensity 4th, 5th and 6th formants are also seen. But F_1 and F_2 are important for determining the vowel quality. F_1 indicates the height of the tongue and F_2 indicates the forward and backward movement of the tongue.[11]

The degree of lip rounding is always small on those formants that belong to cavities behind the tongue constriction as long as the tongue constriction area is smaller than the lip rounding.[12]

So on the basis of F_1 and F_2, which belong to the cavities behind the tongue constriction, it was not possible to make out the degree of lip rounding.

There are generally characterisable features about the nature of formants, whatever be the language under analysis.[13] These features guide the analyst in making judgments about the formants.

The follwing pictures illustrate some of the spectrograms. The formants characteristic of vowels can be clearly seen. The

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11 Eli Fischer-Jørgensen *What can the new Techniques of Acoustic Phonetics contribute to Linguistics* Proce. viii Int. Cong. of Linguists. 1957 page 445.

12 Gunnar Fant *Modern Instruments and methods for acoustic studies of Speech.* RIT Stockholm Technical Report No. 8 1957 p. 19.

13 (a) Gunnar Fant. op. cit. pp. 17-32

(b) L. V. Bondarko *Sound structure of contemporary Russian Language* Moscow 1977 (In Russian) pp. 58.73

fricatives and the frication portion of the affricates having emphasis on the high frequencies may also be noticed. The obsence of F_0 in case of voiceless stops, and the voiceless stop portion of the affricates ; presence of F_0 and the absence of F_1, F_2 etc. in case of voiced stops, which are present again in weak form in case of nasals and laterals may be observed.

3.3 Measurement of Formant Frequencies : Spectrograms are two dimensional pictures of sounds with time along X axis and the frequency along Y axis. The voiceless sounds are distinguished from the voiced ones by the absence or presence of F_0. The central part of the formants is matched with the scale and its frequency is determined. Whenever the formants show the rising or falling shape, the frequencies at the beginning and end are noted down along with the frequency of the prominent central portion. Thus the frequency figures of all the formants of all vowels are noted. Various figures of F_1, F_2 and F_3 of vowels in all their occurrences are totalled and the average frequency of each formant is calculated. In some cases, the frequency figures were far away from the usual range. It would be interesting to study the details of such fluctuation in terms of phonetic environment. It could not be done at the present stage. Dapending upon the proximity of the sound, they were clubbed together.

The intensity of formants was distinguished only on the basis of visual discrimination. It is possible to take the cross section of the formants for intensity. Thus the amplitude would be displayed, which is measurable in decibels. This also could not be done at this stage. The oscillograms have brought out that the vowels in the final position have general low intensity. It would have been possible to quantify the statement if the amplitude display were taken. Hence this point remains unexplored. However the spectrograms also attest that statement by the fact that F_2 & F_3 of final vowels have low visible intensity.

3.4 The scale used : The Koenig scale was printed on a transparent 35mm film which was superimposed on the spectrograms and the formant frequency readings were taken. The scale had the lowest line for 100 c/s and the topmost line for

10,000 c/s. It was observed that the scale from 100 to 10,000 c/s was marked in 22.5 mm space. As the spectrograms appear in 24 mm space, the scale was really a miss–match. When the 100 c/s line of the scale was matched with the base line, or the first channel which filters the frequencies around 100 c/s, the top line of 10,000 c/s of the scale matched in between 45th and 46th channel. The 45th channel filters frequencies around 7900 c/s and 46th channel filters the frequencies around 8,300 c/s.[14] Similarly the 24th channel was marked at the 12th millimeter on the spectrogram. Since the 24th channel filters frequencies around 2100 c/s, at the 12th millimeter, on the scale 2100 c/s should have been indicated. But the scale showed about 2250 c/s at 12th mm. This anomaly in the scale can create a higher reading of F_3 by 100–150 c/s. But in case of F_1 and F_2 the readings are fairly accurate because the anomaly is of a negligible margin.

3.5 Results of the analysis :

The average frequencies of F_1, F_2 and F_3 of six short vowels and six long vowels are tabulated below.

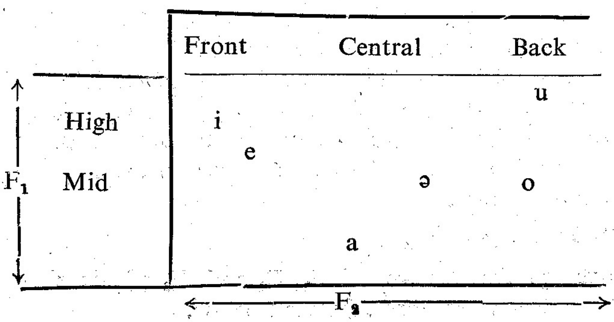
Table showing the Formant frequencies

Vowel	F_1 c/s	F_2 c/s	F_3 c/s
i	280	2200	2800
i:	305	2300	3100
e	400	2000	3500
e:	500	2200	3500
a	750	1500	2500
a:	800	1400	2600
ə	500	1200	2500
ə:	500	1200	2500
o	500	1000	2200
o:	600	1000	2500
u	260	460	1000
u:	300	500	1000

14 These figures are taken from the technical data on the *Spectrograph* machine.

3.6 Graphic representation of formants

The following graph–1 shows the relative positions of F_1 and F_2 of six short and six long vowels. It is evident from the graph that the formants present almost the same vowel triangle with a little difference. If a vowel triangle is designed on the basis of the information conveyed by the formants it will be as follows :

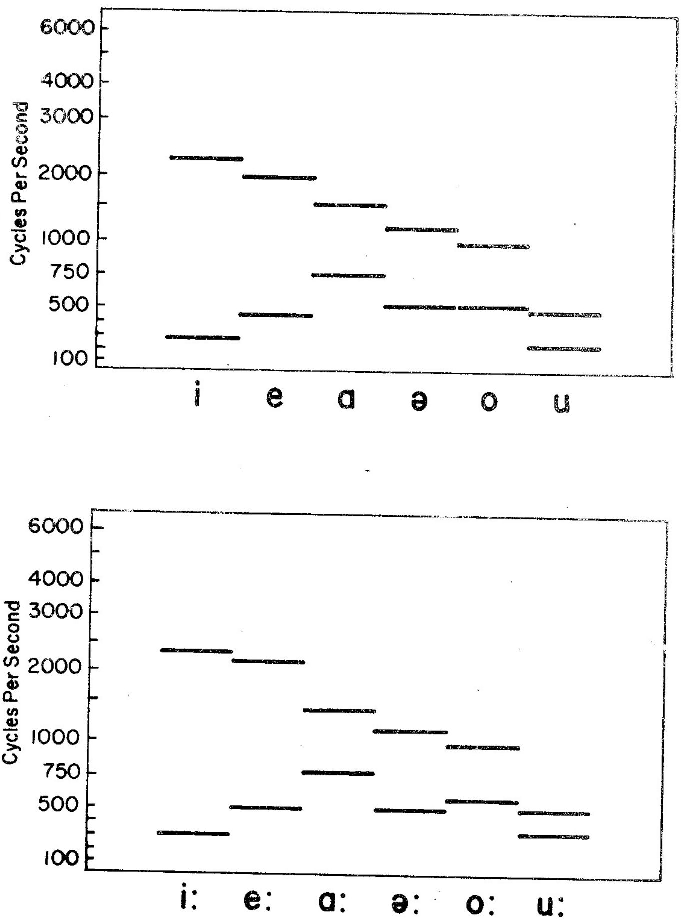


[u] is slightly higher than [i]. But [o] and [ə] are of the same height. [ə] and [o] are lower than [e], which is slightly above the mid.

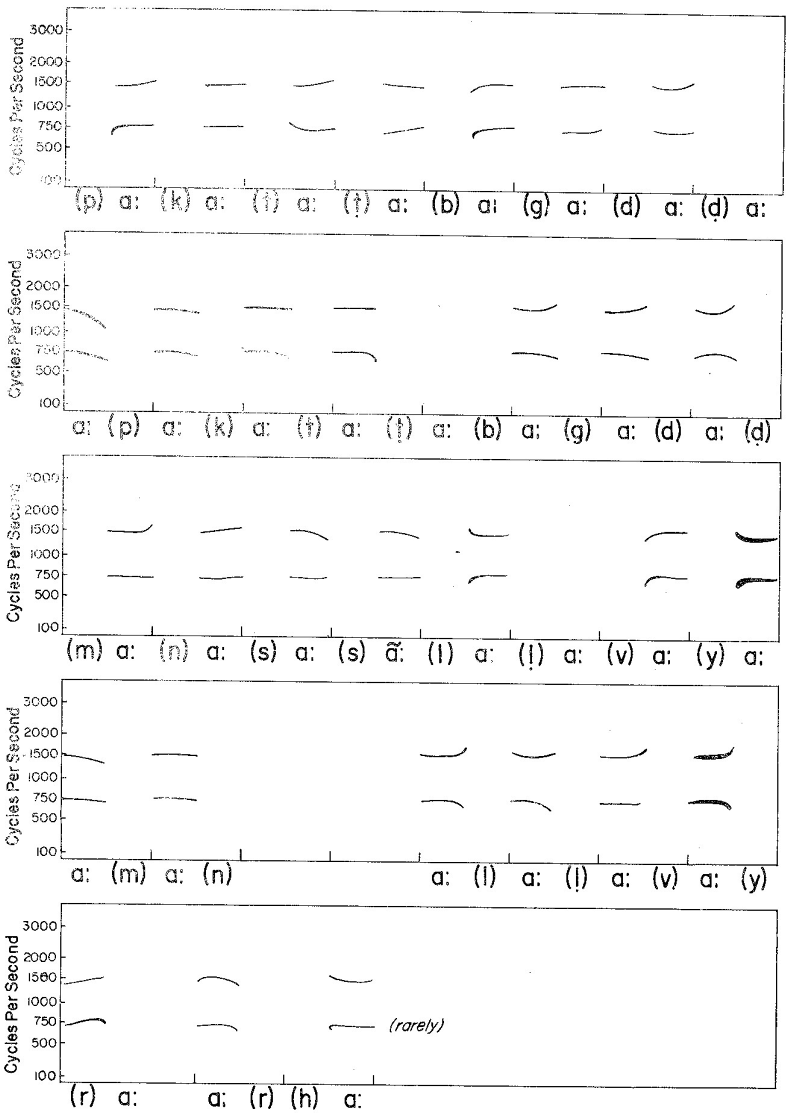
[i] is fronter than [e] which is fronter than [a] which is again fronter than [ə]. [o] is fronter than [u].

Graph 2 shows the shapes of F_1 and F_2 of vowel [a:] before and after the stops, nasals, liquids, semivowels and [h]. The influence of other fricatives could not be generalised. The same was the case with the affricates, because the affrication portion of the affricates had similar acoustic structure, with lesser intensity, to fricatives.

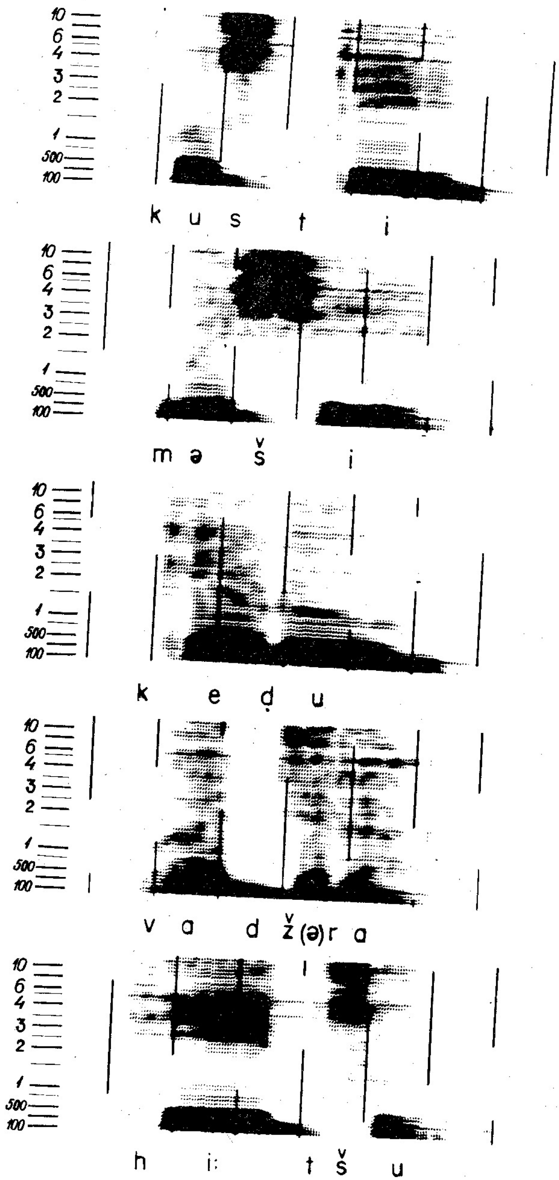
The shapes of the formants are characterised by rising slope or falling slope ; beginning with a bend or ending with a bend ; concave or convex, darker or lighter in shade. If F_1 is similar in two cases, the F_2 would be different. The other vowels did not show such marked difference in their formant shape. Hence vowel [a:] has been chosen for the display.

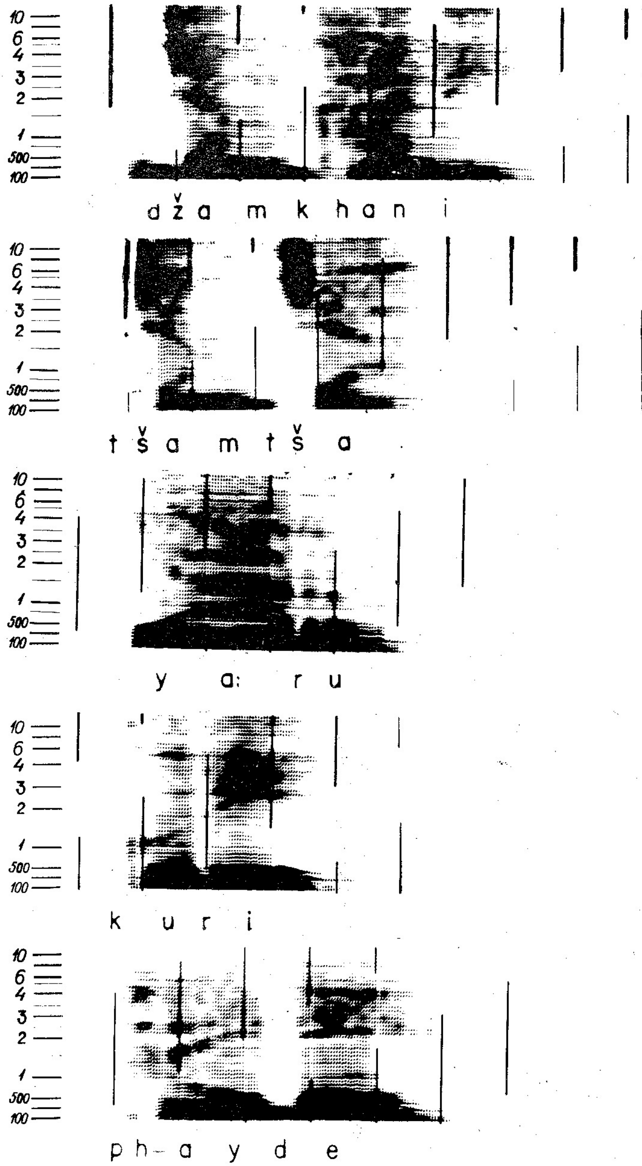

6000
4000
3000
2000
1000
750
500
100
Cycles Per Second
i e a ə o u
i: e: a: ə: o: u:

Graph 1


Cycles Per Second
3000
2000
1500
1000
750
500
100
(p) a: (k) a: (t) a: (ṭ) a: (b) a: (g) a: (d) a: (ḍ) a:
a: (p) a: (k) a: (t) a: (ṭ) a: (b) a: (g) a: (d) a: (ḍ)
(m) a: (n) a: (s) a: (s) ã: (l) a: (ḷ) a: (v) a: (y) a:
a: (m) a: (n) a: (l) a: (ḷ) a: (v) a: (y)
(rarely)
(r) a: a: (r) (h) a:

Graph 2


10
6
4
3
2
1
500
100
k u s t i
m ə š i
k e ḍ u
v a d ž(ə)r a
h i: t š u


10
6
4
3
2
1
500
100
džamkhani
tšamtša
ya:ru
kuri
ph-ayde

Though those would be the general shapes of F_1 & F_2 of [a:] they show marginal deviation in different phonetic environments.

A blank indicates non–occurrence in the data.

3.7 Observations on the basis of Spectrographic analysis

Unlike in the oscillographic analysis, in spectrographic analysis all the sounds are interpretted on the basis of the formant structures of vowels only. So the following observations, made while analysing the spectrograms are naturally in the light of the formants of vowels. It may be pointed out that the duration of sounds can be better studied on the oscillograms rather than on spectrograms. Because the space on the spectrograms is less when compared to that on oscillograms. Since each spot on the spectrogram counts four milliseconds, the duration can be only in the multiples of four. Moreover the duration of voiceless stops cannot be precisely measured as they show no formants.

It was generally observed that higher the vowel, lower was F_1 and conversely lower the vowel, higher was F_1. This fact has been well displayed by graph 1. With this rule it was possible to determine the quality of vowels. The formants moved upward or downward by 100–150 cps. If the phonetic environment was responsible for this shift, then those sounds could be established as allophones. In the absence of such evidence, they were treated as fluctuations of the same vowel. The fluctuations were normalised by averaging.

The long vowels showed their formants 100–150 c/s higher than their short counterparts. Same was the case when the vowels were pronounced with emphasis. This observation may be an accident unless established by further experiments.

Though the frequencies of F_1 of [ə] and [a] were around 500 cps and 800 cps respectively, in certain cases the vowels showed 600 or 650 cps. It means that a vowel of the tongue height in between [ə] and [a] was possible to be indentified. It could be [ʌ]. It occurred before geminated velar voiceless stop. But the phonetic enviroments of its other occurrence could not be ascertained at this stage.

[e] in the final position showed F_1 with 500 cps, as against 400 cps elsewhere. This confirms the lower variety allophone [E] in the word final position.

Similarly, [o], when followed by [a] in the next syllable, showed F_1 with 600 cps, as against 500 cps elsewehre. This confirms the allcphone [ɔ].

As has been observed in the oscillographic analysis that most of the vowels showed fast declining intensity in the final position, the spectrograms showed very weak F_2 and F_3. In case of final [u] only F_1 and F_2 were seen.

[y] and [v] showed formant structures comparable to [i] and [u] respectively.

Though it was not possible to characterise the voiceless stops on the basis of oscillograms, it was possible on the basis of spectrograms with the help of the shape of F_1 of vowel [a:], in the following position. Similarly it is possible to characterise the voiced stops, nasals, liquids and semivowels as has been shown in graph 2.

The occlusion of voiceless stops was clearly identifiable when the F_0 gradually sank into blank, whereas in case of voiced stops though F_0 continued, the occlusion marked a depression in F_0.

The line of burst or plosion was clearly visible in almost all stops. F_0 of the following vowel showed a hump to mark the plosion and the line continued upto very high frequencies—up to 8000 or 9000 cps. It showed more intensity at 1000, 1500 or 3000 cps frequency levels. Sometimes it was broken generally between 1500–3000 c/s frequency level. At the end of some words a glottal stop was articulated. That also showed the same line of burst.

The plosion or burst and frication have similar shape except that the frication has more high frequency emphasis.

The aspirated consonants showed four elements : stop portion + plosion + frication + aspiration or [h]. The aspiration showed a voiceless form of the following vowel. That is, in aspiration F_0 was absent whereas F_2 and F_3 (some times F_1 also) were marked on the same level as the F_2 and F_3 (&F_1) of the following vowel, but with lesser intensity. In some cases of voiced aspirates, F_0 was also present.

[ḍ] as plosive could not be distinguished from [ð̣] a flap as they did not show any characteristic difference. Similarly [d] and [ð] or [b] and [b̲] or [g] and [g̲] also could not be distinguished on the spectrograms. This means that [ð b̲ g̲] are not fricatives. If they were, the noise would have shown up at high frequencies. It may be argued that they are lenis varieties of the respective stops.

Fricatives [š] [ṣ] and [s] are high frequency noises between 3500 cps and 10,000 cps. The intensity of [š] is the highest and that of [s] is the lowest. In between is the intensity of [ṣ]. [h] in isolation differs from the other fricatives. It has the same but very weak F_2 and F_3 as the following vowel. Since it is a voiceless sound F_0 is absent. Along with that, F_1 is also absent. But rarely F_1 is marked with very low intensity.

After the liquids F_1 of [a] is higher by 100–150 cps.

The vowel released between the consonants in cluster had very weak formants. Since its F_1 appeared at higher level than that of [ə], the released vowel is of [a] quality.

The nasalization was marked by weak F_1, and F_2 was not so steep falling as of non nasalised vowel. The graph–2 shows the distinction.

These observations will have to be checked with other speakers in order to get established. However they give a deeper insight into the structure of Kannada sounds.

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It is for the first time that a full length oscillographic and spectrographic study is made about an Indian language, with a view to examining the utility of acoustic analysis for phonemics. The acoustic study has been made using the Russian methodology. Though brief, the results have far reaching effect in the understanding of the acoustic characteristics of Kannada. This is a significant contribution to the acoustic study as well as to the phonetics of Kannada.

COVER DESIGNED AND PRINTED
AT THE CIIL PRESS, MYSORE.